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TECHNICAL REPORT

FROST DEGREE DAY, RELATED ICE THICKNESS CURVES, AND HARBOR FREEZEUP AND BREAKUP DATES FOR SELECTED ARCTIC STATIONS

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ABSTRACT

Frost degree day data and sea ice information for selected stations throughout the Arctic are described. Related frost degree day and ice growth curves are graphically illustrated. Harbor breakup and freezeup dates are furnished for selected stations.

FOREWORD

Successful arctic operations require considerable preparation and planning. To aid such planning, the Oceanographic Office has been engaged in developing various techniques for forecasting formation, growth, movement, and disintegration of sea ice, especially in harbor areas, since each arctic and subarctic harbor constitutes a special environmental problem.

This report is based on available sea ice information and frost degree data for 58 arctic stations. Freezeup and breakup dates for 39 stations are included. The earliest, latest, and average dates of freezeup or breakup are given in calendar dates.

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17. Gambell	36-37	46. Dundas Harbor	94-95
18. Nunivak	38-39	47. Arctic Bay	96-97
19. Bethel	40-41	48. Pond Inlet	98-99
20. Naknek	42-43	49. Herschel Island	100-101
21. St. Paul Island	44-45	50. Aklavik	102-103
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I. INTRODUCTION

This report presents available frost degree day data and sea ice information for selected arctic harbors. Emphasis is placed on three general categories of data: (1) cumulative frost degree days, (2) ice growth and disintegration, and (3) harbor breakup and freezeup dates.

II. METHOD OF COMPILATION

A. Frost Degree Days

Frost degree day curves were drawn for the 58 arctic and subarctic stations identified in figure 1 and listed in table 1. A frost degree day is defined as a daily mean temperature 1°F below an arbitrary base of 32°F. The frost degree day curves were based on mean monthly, mean daily maximum, and mean daily minimum temperatures. These three parameters were used to construct corresponding frost degree day curves, which give a normal frost degree day accumulation, and an envelope showing maximum and minimum frost degree day values for each station. These curves, together with a mean temperature curve, are shown in figures 3A through 60A.

b. Ice Growth

Associated with the frost degree day curves are corresponding ice growth and disintegration curves (figures 3B through 60B). Two types of ice growth curves are depicted in this report: (1) a theoretical curve based on cumulative frost degree days, and (2) an empirical curve based on observed ice thickness data. At the stations where ice thickness data were available for at least 3 years, empirical curves were constructed for normal ice growth, as well as for the maximum and minimum growth. For stations which lacked ice thickness data, a theoretical curve was constructed from a variation of the Zubov ice growth curve given by the following:

$$1.43I^2 + 28.6I - \sum FDD = 0$$

where I is ice thickness, and FDD is the summation of the cumulative frost degree days in degrees Fahrenheit. An average date for theoretical complete disintegration of the ice was also computed. The period between maximum ice growth and complete disintegration of the ice for each station was based upon available ice information. Initial ice growth and rate of disintegration for the empirical and several theoretical ice growth curves were estimated and are indicated by broken lines in the figures. The sparsity of freezeup and breakup data at the individual stations made this estimation necessary.

III. HARBOR BREAKUP AND FREEZEUP DATES

Harbor freezeup data were compiled for the 39 arctic and subarctic stations listed in table 2. Breakup data were sufficient for only 30 stations. The data for each particular station were divided into three main categories based on calendar dates. These categories consisted of earliest, latest, and average dates of breakup or freezeup. Freezeup is defined as the date of initial ice formation. Breakup is the date when

ice concentration decreases to one tenth or less in a given harbor. It is to be emphasized that breakup dates apply only to the harbor at the specified stations. Quite often, the harbor will become essentially ice free, but the approaches to the station may still be congested with heavier ice concentrations.

IV. SUMMARY

This report shows the relationship between ice growth and air temperature. An average date based upon available ice information was computed for disintegration of ice at various stations. The relationship between the number of warming degree days and melting of specific maximum ice growths is not discussed in this report. It should be stressed that other parameters, such as ocean currents, winds, and tidal action, also affect ice growth and dissipation at some locations. Further study of these parameters is currently being conducted.

Table 1

Location Identifier for Frost Degree Day and Ice Growth Curves

1.	*Barter Island	21.	Thule	41.	Isachsen
2.	Pt. Barrow	22.	Clyde River	42.	Mould Bay
3.	Wainwright	23.	Padloping Island	43.	Resolute
4.	Pt. Lay	24.	Frobisher Bay	44.	Dundas Harbor
5.	Pt. Hope	25.	Resolution Island	45.	Arctic Bay
6.	Kotzebue	26.	Hopedale	46.	Pond Inlet
7.	Wrangel Island	27.	Goose Bay	47.	Herschel Island
8.	Mys Schmidta	28.	Cartwright	48.	Aklavik
9.	Mys Vankarem	29.	Belle Isle	49.	Coppermine
10.	Mys Dezhneva	30.	Upernavik	50.	Cambridge Bay
11.	Uelen	31.	Umanak	51.	Lake Harbour
12.	Mys Chaplina	32.	Godhavn	52.	Nottingham Island
13.	Wales	33.	Jakobshavn	53.	Coral Harbor
14.	Nome	34.	Sondrestrom	54.	Chesterfield
15.	Gambell	35.	Godthaab	55.	Churchill
16.	Nunivak	36.	Ivigtut	56.	Port Harrison
17.	Bethel	37.	Nanortalik	57.	Cape Hopes Advance
18.	Naknek	38.	Angmagssalik	58.	Fort Chimo
19.	St. Paul Island	39.	Nord		
20.	Alert	40.	Eureka		

* Numbers agree with those shown in figure 1.

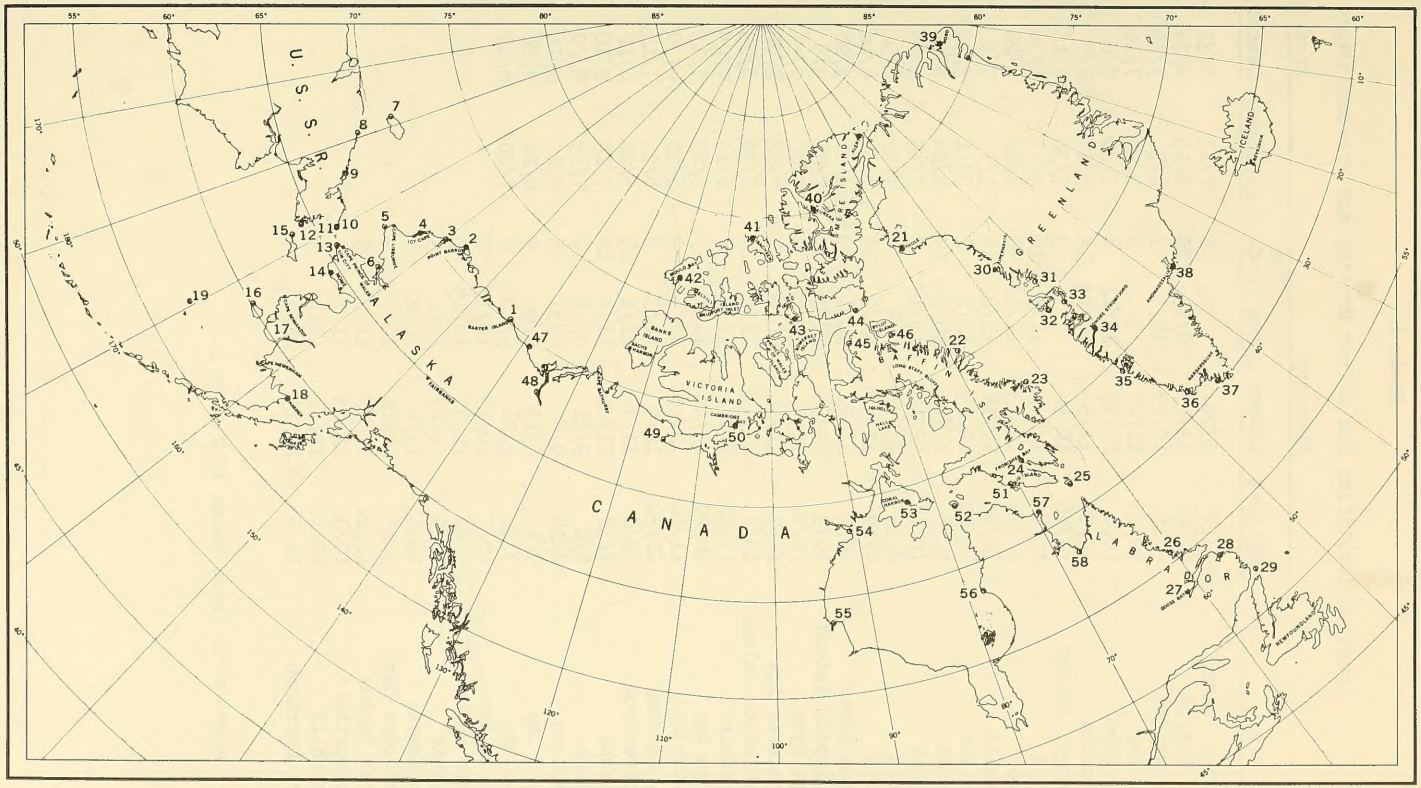

FIGURE I LOCATION MAP FOR FROST DEGREE DAY AND ICE GROWTH AND DISINTEGRATION CURVES

Table 2

Location Identifier for Harbor Breakup and Freezeup Dates

	Site	Freezeup Earliest	Freezeup Latest	Freezeup Avg	Freezeup Yrs Data	Breakup Earliest	Breakup Latest	Breakup Avg	Breakup Yrs Data
1.	*Barter Island	9/24	9/24		1	7/15	8/31	8/13	3
2.	Pt. Barrow	8/30	12/19	9/17	25	6/15	8/24	7/24	25
3.	Wainwright	9/16	10/25	10/5	8	6/7	7/26	7/5	7
4.	Pt. Lay	10/15	11/27		4	5/20	7/10	6/15	3
5.	Pt. Hope	10/6	12/19	11/11	8	5/30	7/8	6/20	8
6.	Kotzebue	10/2	11/5	10/23	14	5/17	6/8	5/31	14
7.	Wrangel Island	10/18	12/4		3	7/30	8/16		4
8.	Wales	10/8	1/8	12/3	16	5/15	6/30	6/8	16
9.	Nome	10/13	12/13	11/12	50	4/28	6/28	5/29	50
10.	Gambell	10/15	12/14	11/21	10	5/1	7/1	5/26	10
11.	Nunivak	11/20	12/13	12/1	2	5/11	5/30	5/20	2
12.	Bethel	10/8	11/24	10/29	27	4/24	5/28	5/15	27
13.	Naknek	10/17	12/15	11/17	7	3/19	4/25		7
14.	Alert	8/27	9/17	9/3	4	7/31	8/5	8/2	2
15.	Thule	9/19	11/1	10/9	15	7/8	8/16	7/22	11
16.	Clyde River	10/1	11/11	10/19	9	8/16	9/28	9/3	6
17.	Padloping Island	10/3	11/24	10/26	10	7/31	9/8	8/24	6
18.	Cape Dyer	10/3	11/7	10/19	7	7/28	9/1	8/20	6
19.	Frobisher Bay	10/9	11/14	10/24	11	7/28	8/28	8/16	6
20.	Resolution Island	10/9	11/18	11/6	10	6/30	8/25	7/23	6
21.	Hopedale	11/12	12/14	11/23	8	6/15	7/25	7/11	6
22.	Goose Bay	10/20	11/24	11/14	19	5/25	7/15	6/25	11
23.	Cartwright	11/12	12/16	12/1	9	5/25	6/30	6/17	6
24.	St. Anthony	11/30	12/5	12/3	3	5/3	7/13	6/8	6
25.	Sondrestrom	10/8	11/7	11/1	15	5/22	6/12	6/7	11
26.	Kulusuk	9/30	11/26	11/4	12	7/15	9/10	8/12	10
27.	Eureka	9/6	9/21	9/13	6	7/15	8/20	7/28	5
28.	Isachsen	8/24	9/6	8/31	5	8/1	8/16	8/10	3
29.	Mould Bay	9/1	9/15	9/6	4	8/20	8/26	8/23	2
30.	Resolute	9/12	9/26	9/19	9	7/20	8/13	7/29	4
31.	Arctic Bay	10/7	10/19	10/13	3				
32.	Sachs Harbor	9/28	10/31	10/15	7				
33.	Aklavik	10/9	10/27	10/16	3				
34.	Coppermine	10/16	11/4	10/26	5				
35.	Cambridge Bay	9/25	10/16	10/7	5				
36.	Coral Harbor	10/21	11/26	11/7	5				
37.	Chesterfield	10/30	11/15	11/7	4				
38.	Churchill	10/17	11/19	11/7	3				
39.	Port Harrison	11/5	11/13	11/9	3				

* Numbers agree with those shown in figure 2.

FIGURE 2 LOCATION MAP FOR HARBOR BREAKUP AND FREEZEUP DATES

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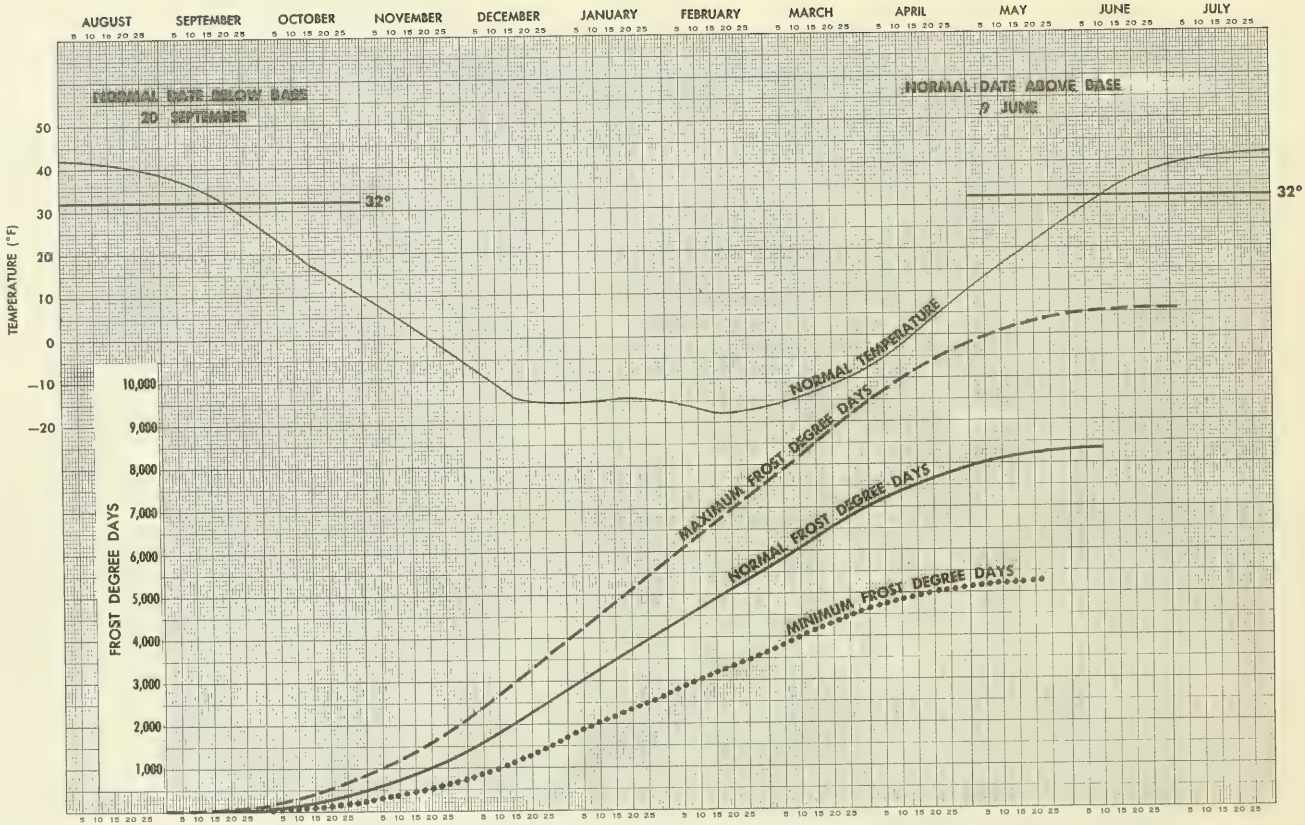

FIGURE 3A BARTER ISLAND (9 YEARS RECORD)

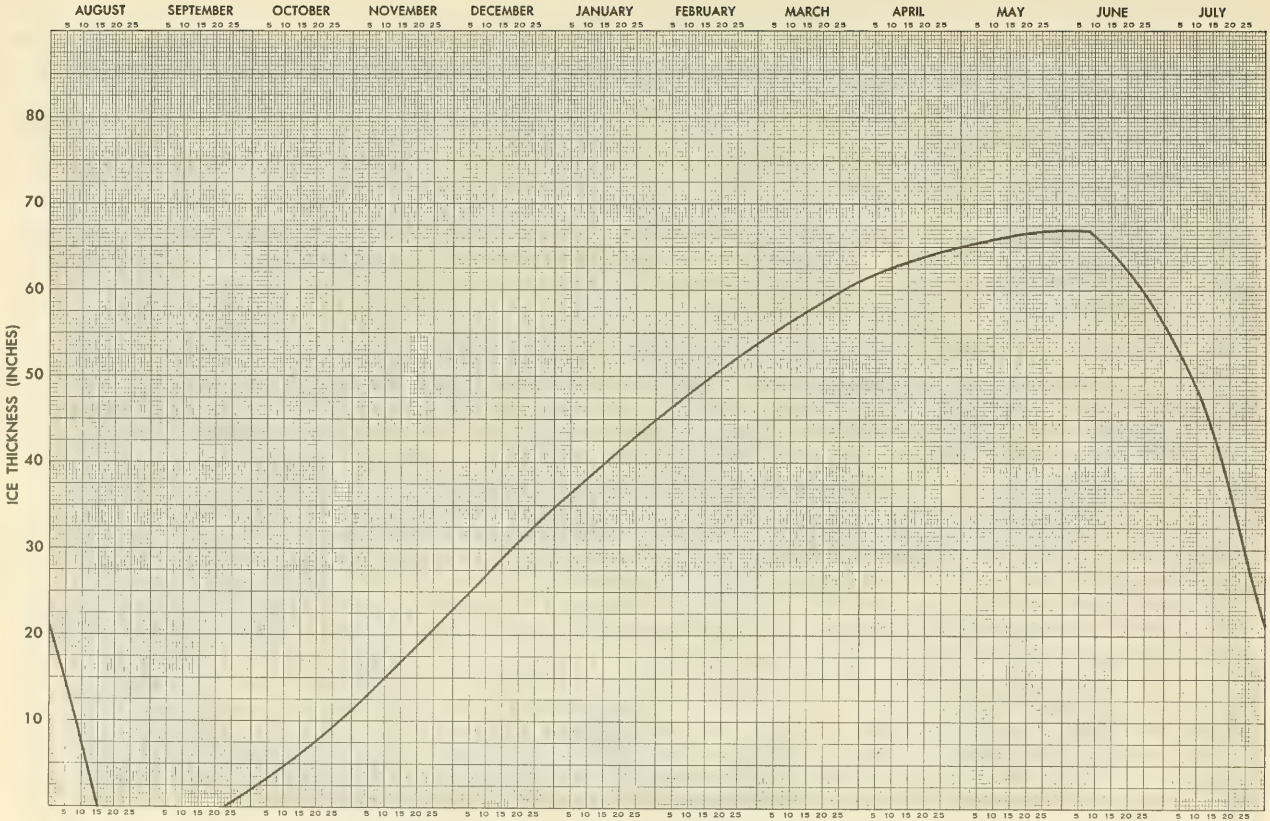

FIGURE 3B BARTER ISLAND THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

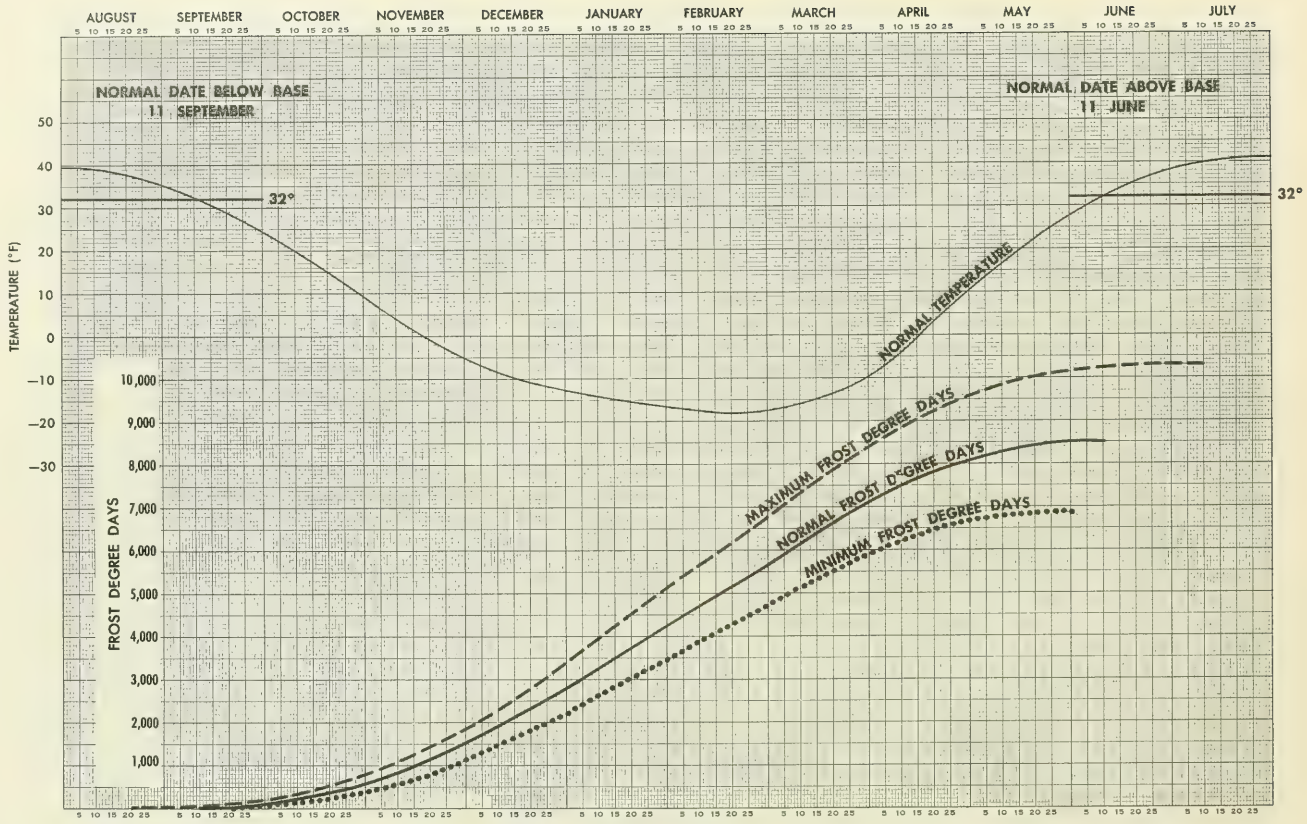

FIGURE 4A POINT BARROW (30 YEARS RECORD)

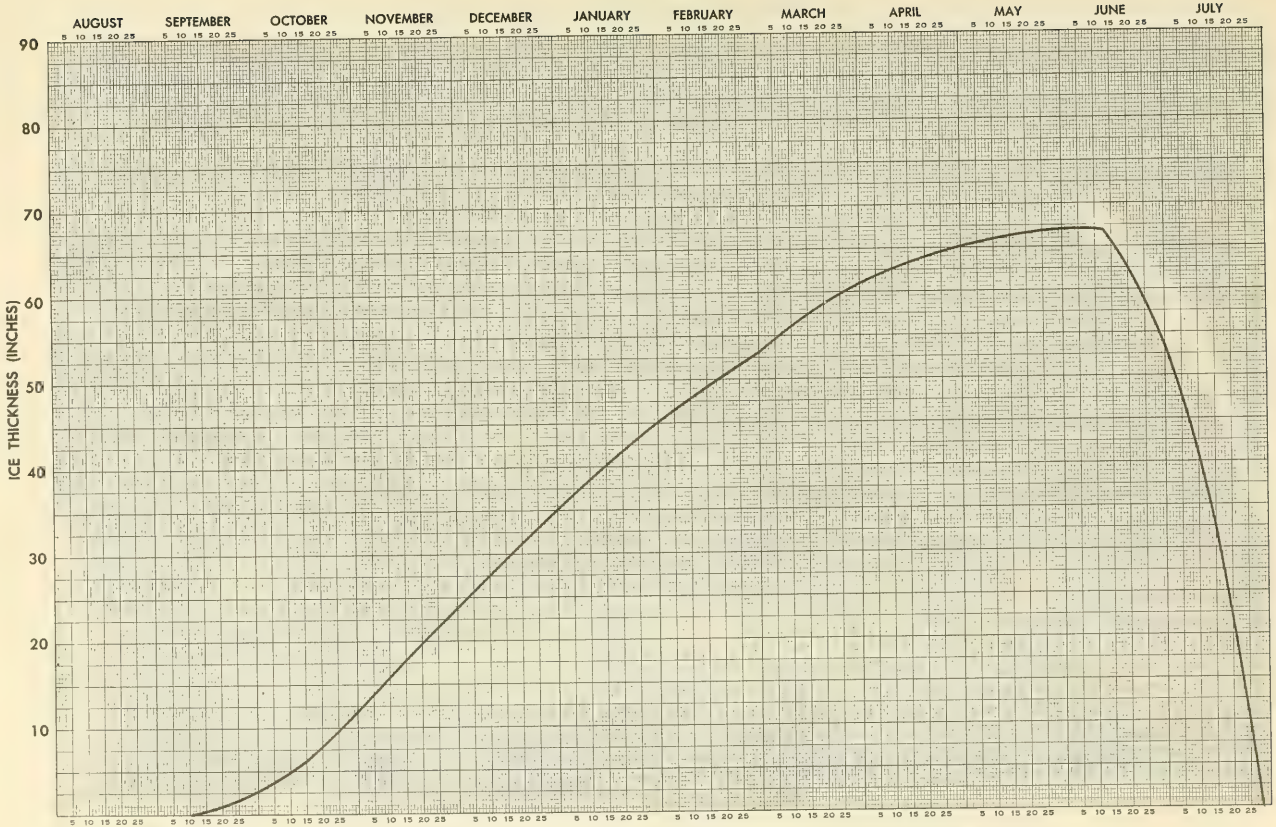

FIGURE 4B POINT BARROW THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

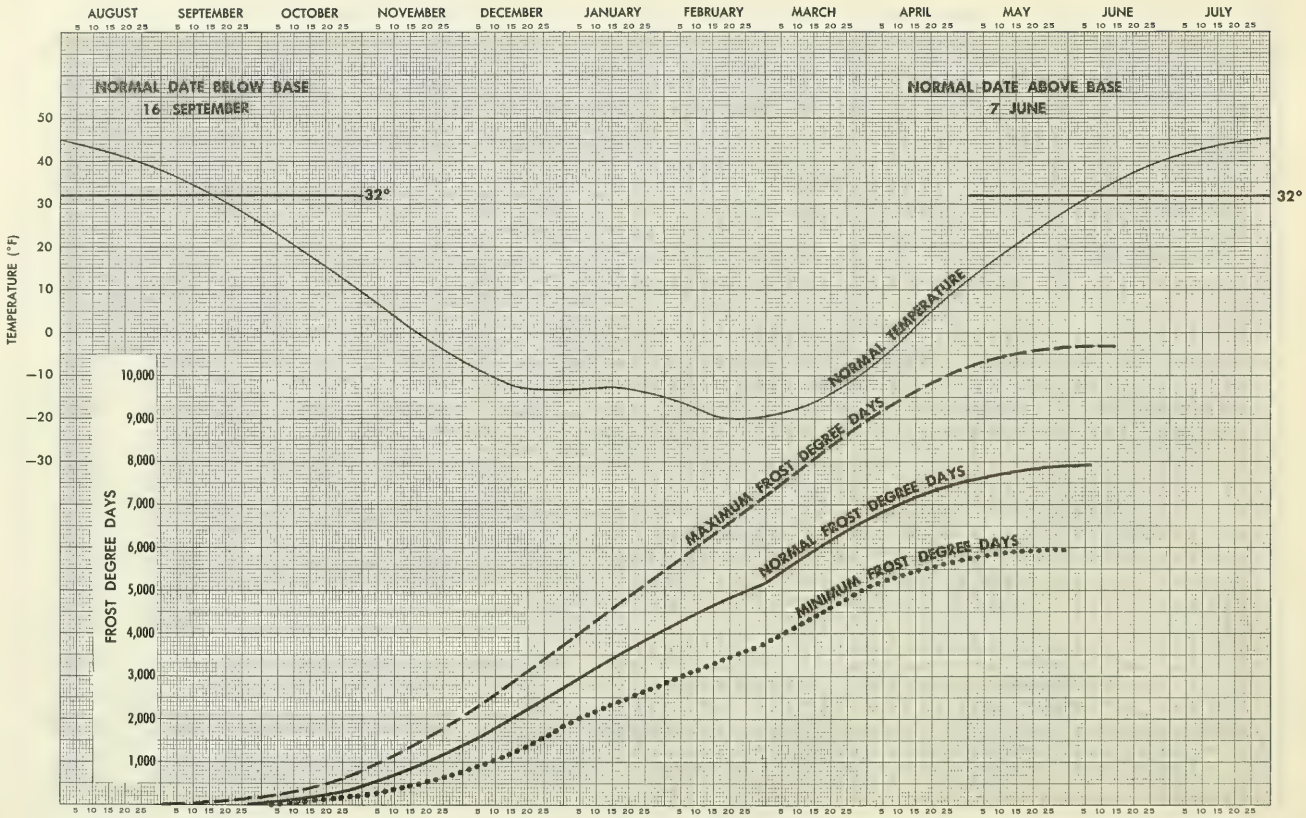

FIGURE 5A WAINWRIGHT (10 YEARS RECORD)

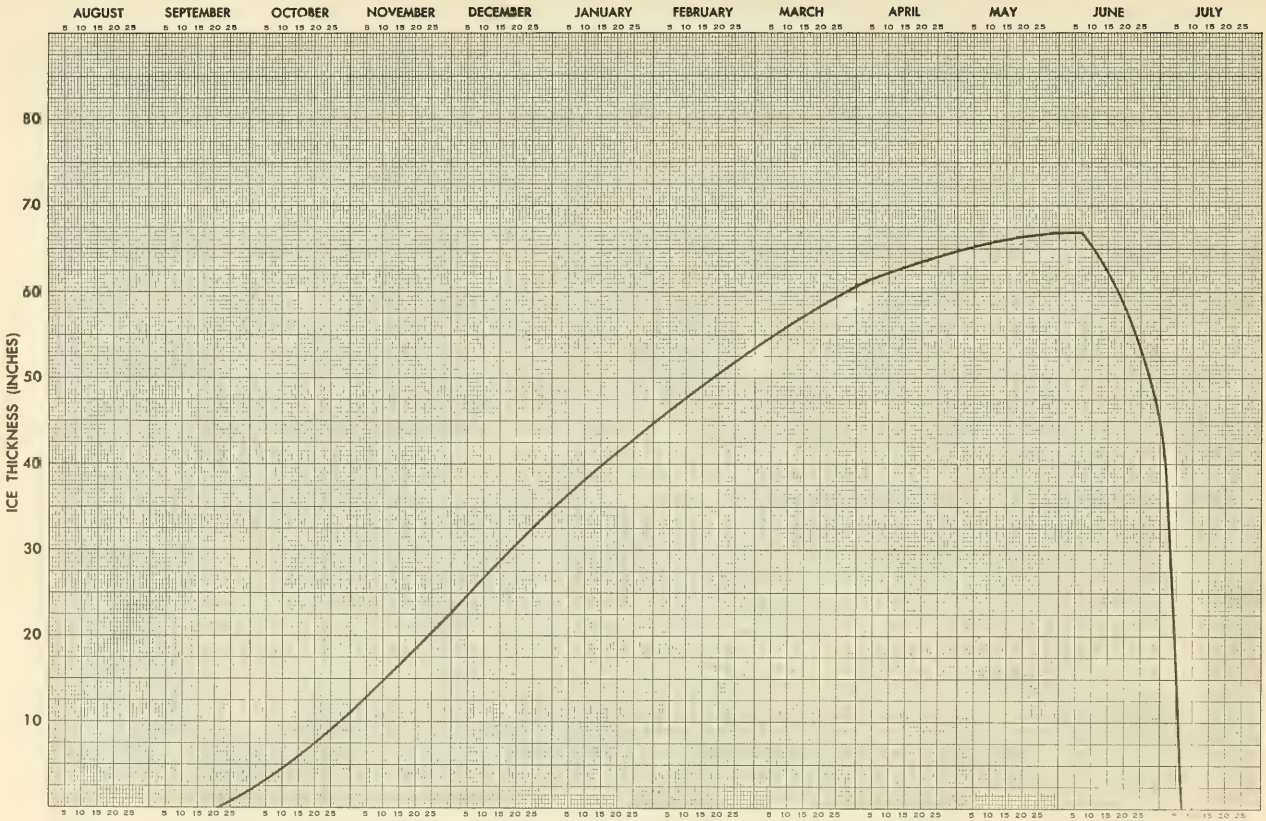

FIGURE 5B WAINWRIGHT THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

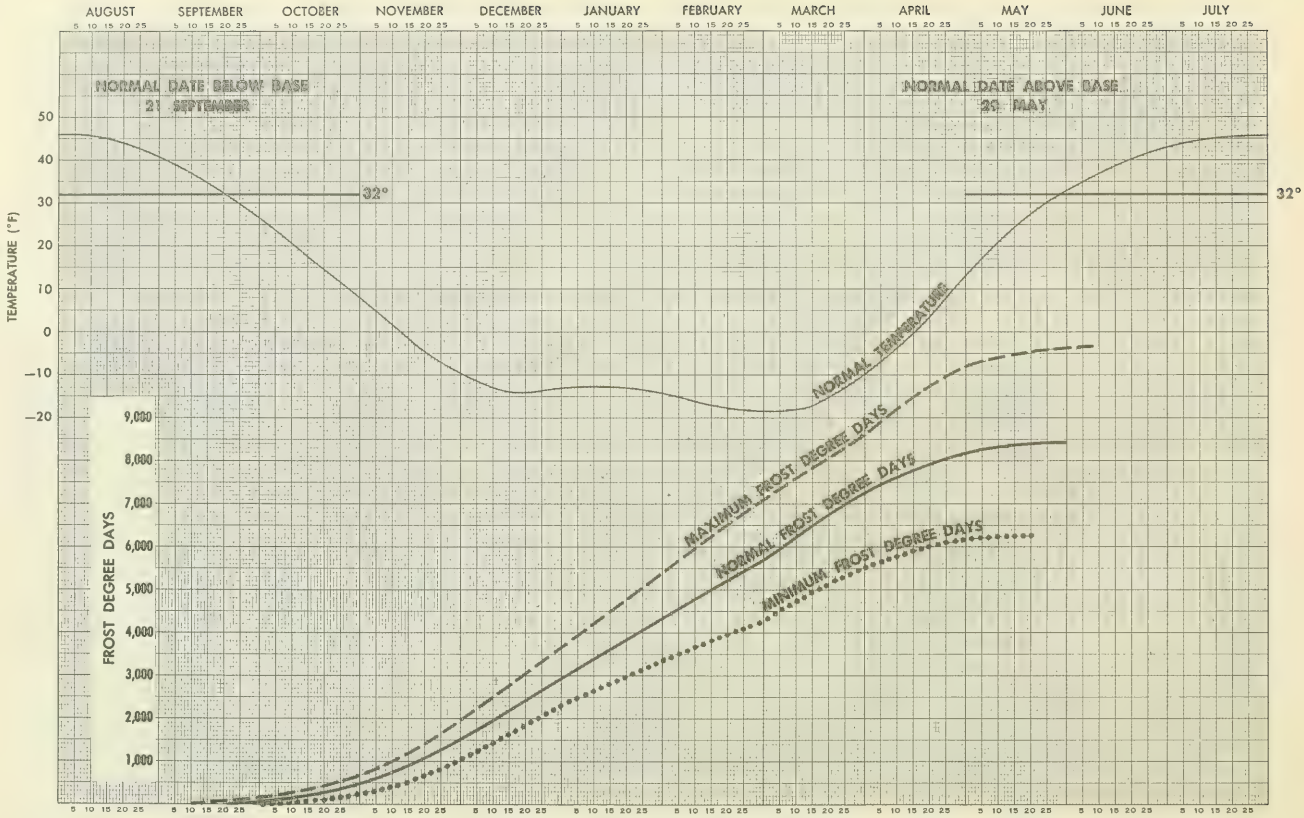

FIGURE 6A POINT LAY (8 YEARS RECORD)

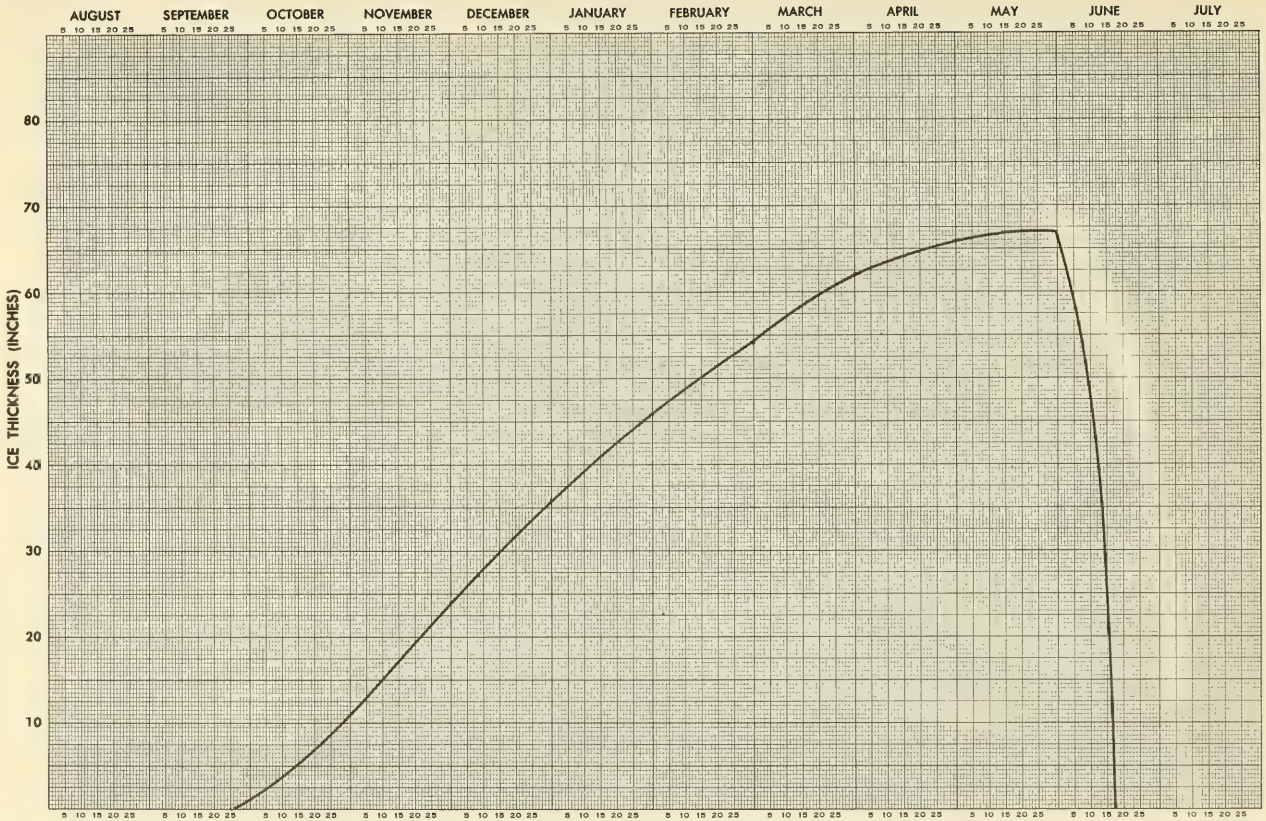

FIGURE 6B POINT LAY THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

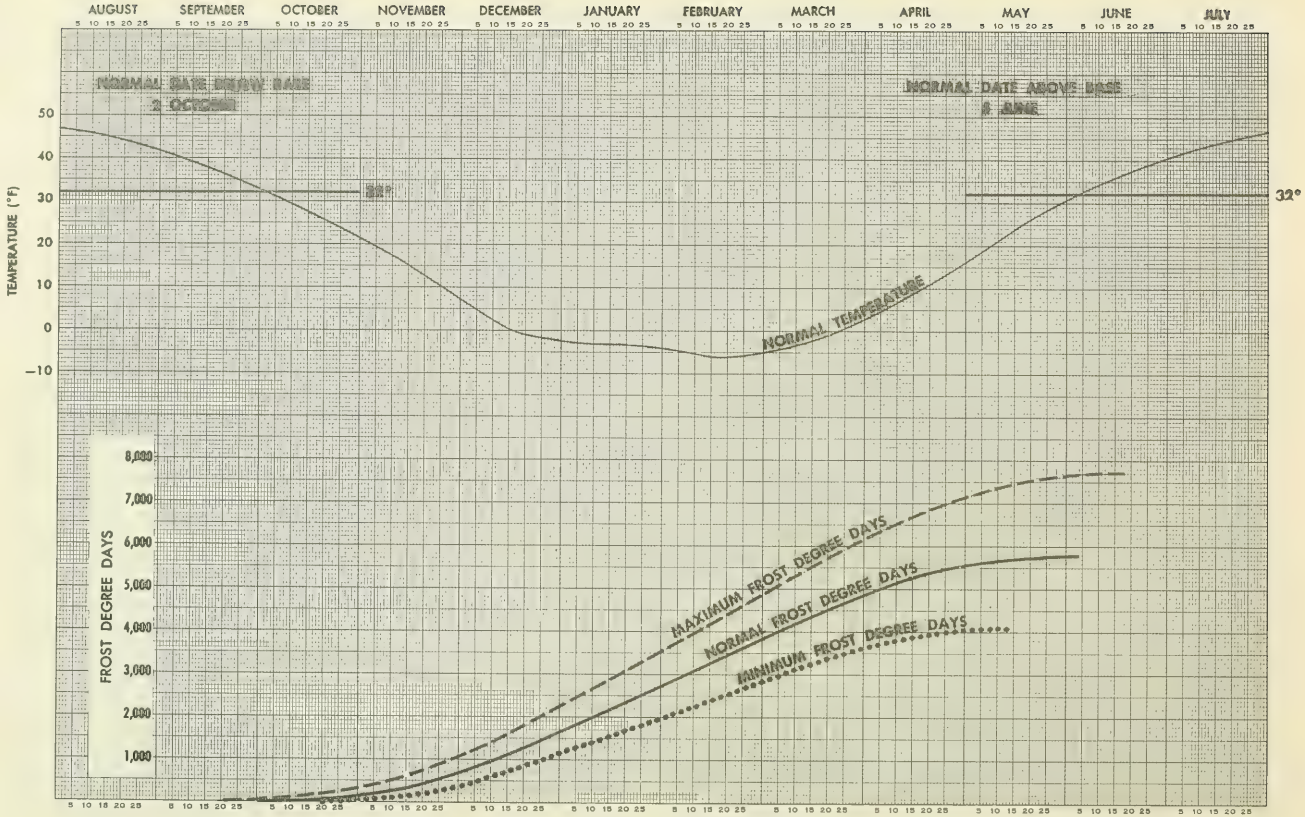

FIGURE 7A POINT HOPE (8 YEARS RECORD)

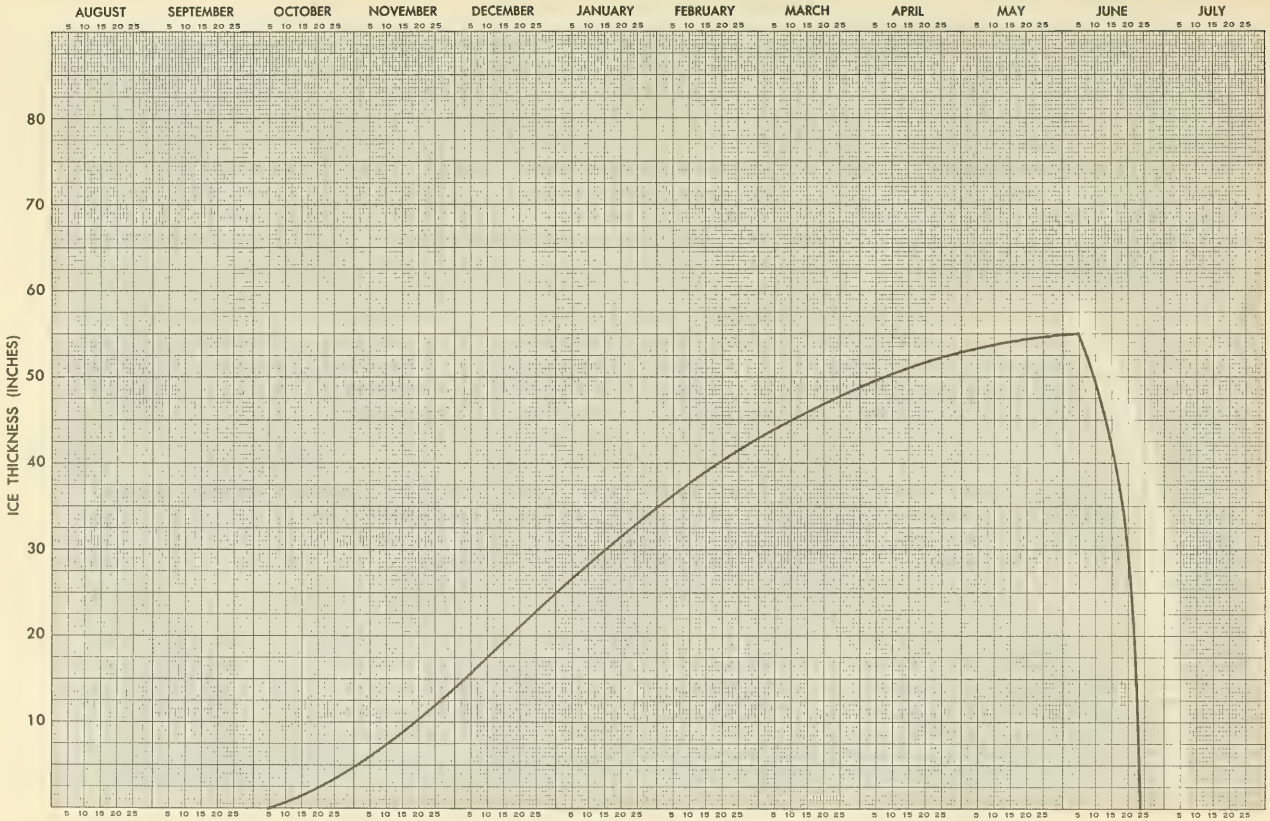

FIGURE 7B POINT HOPE THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

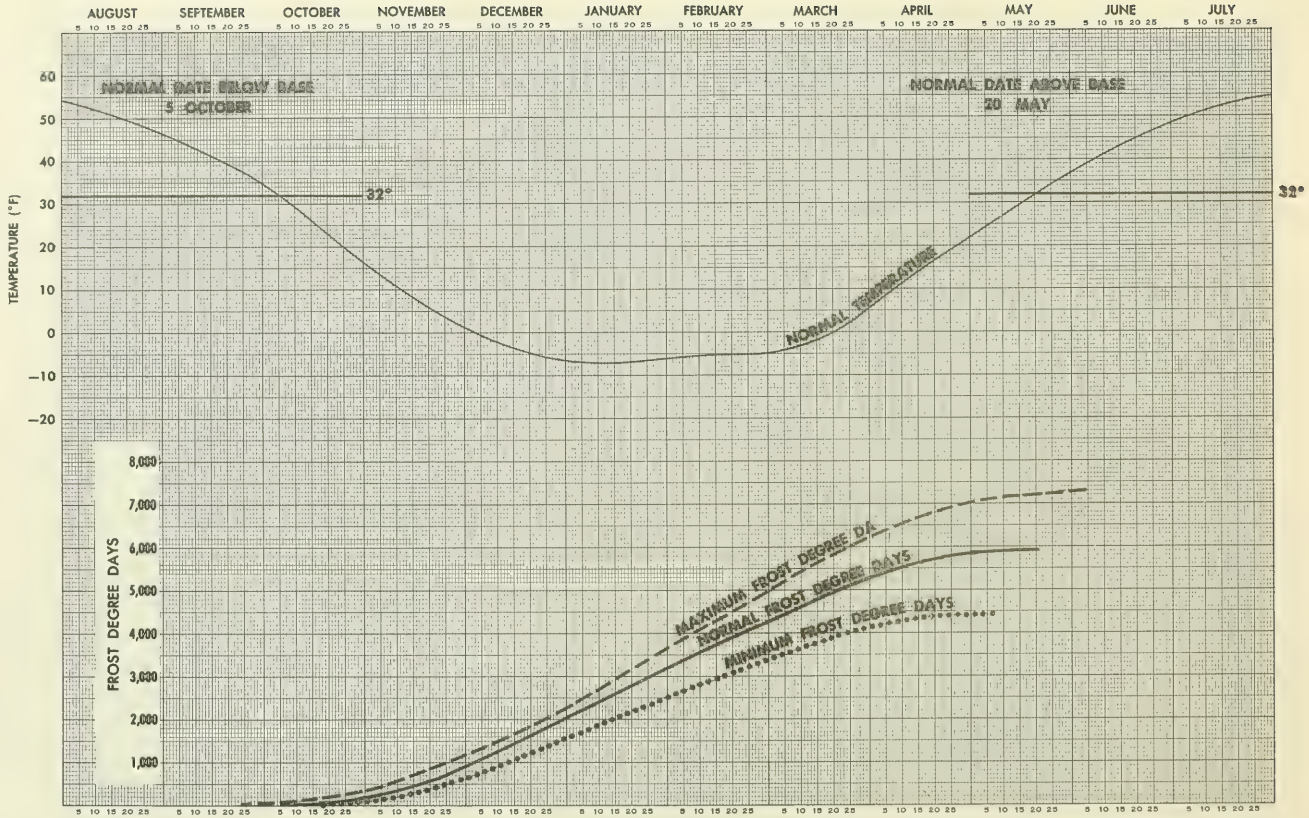

FIGURE 8A KOTZEBUE (30 YEARS RECORD)

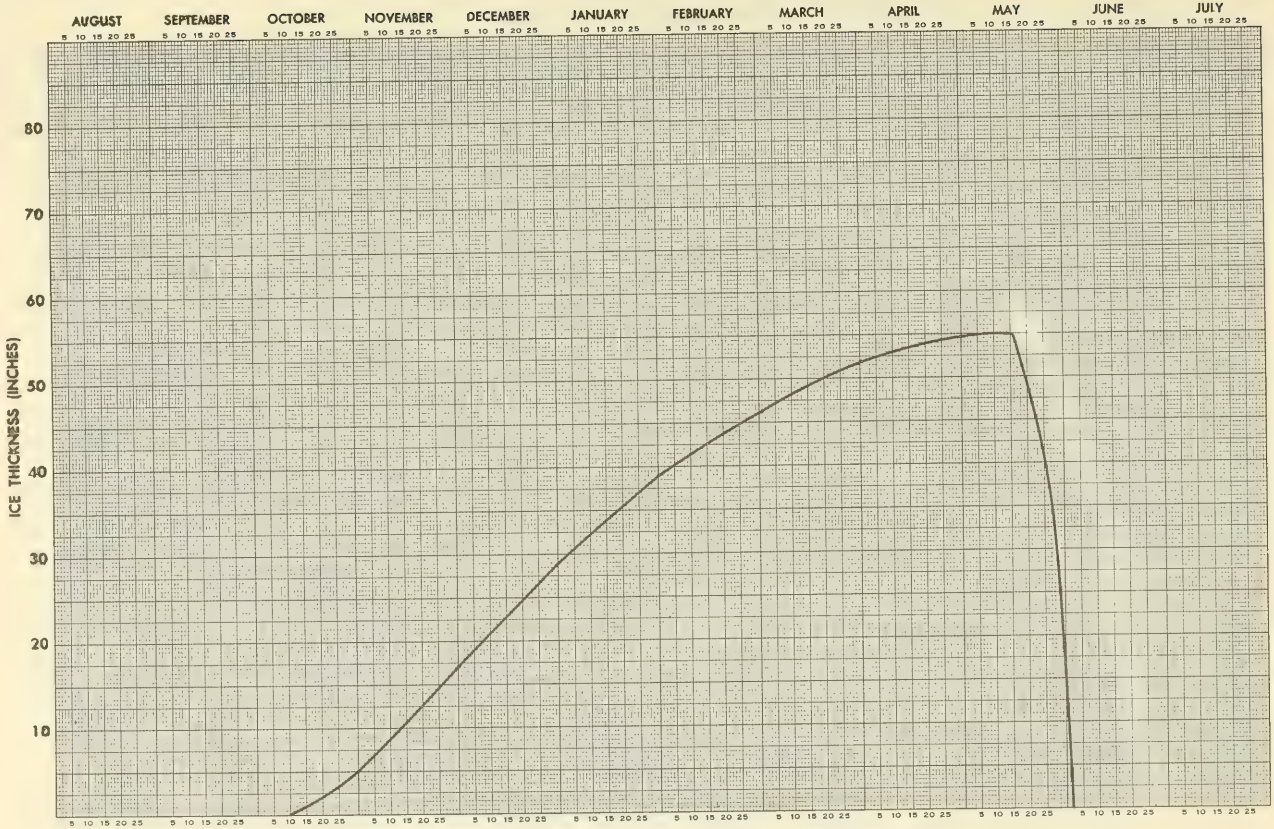

FIGURE 8B KOTZEBUE THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

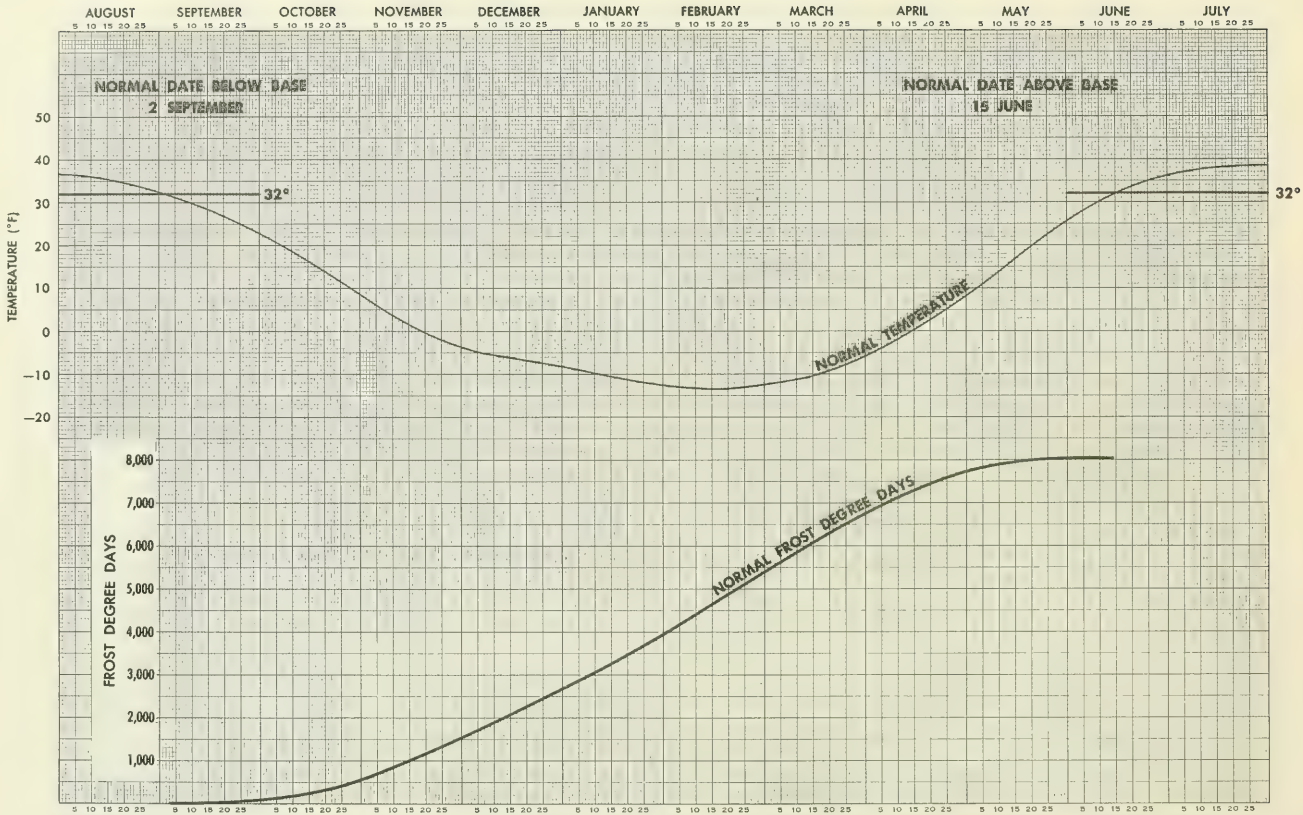

FIGURE 9A WRANGEL ISLAND (9 YEARS RECORD)

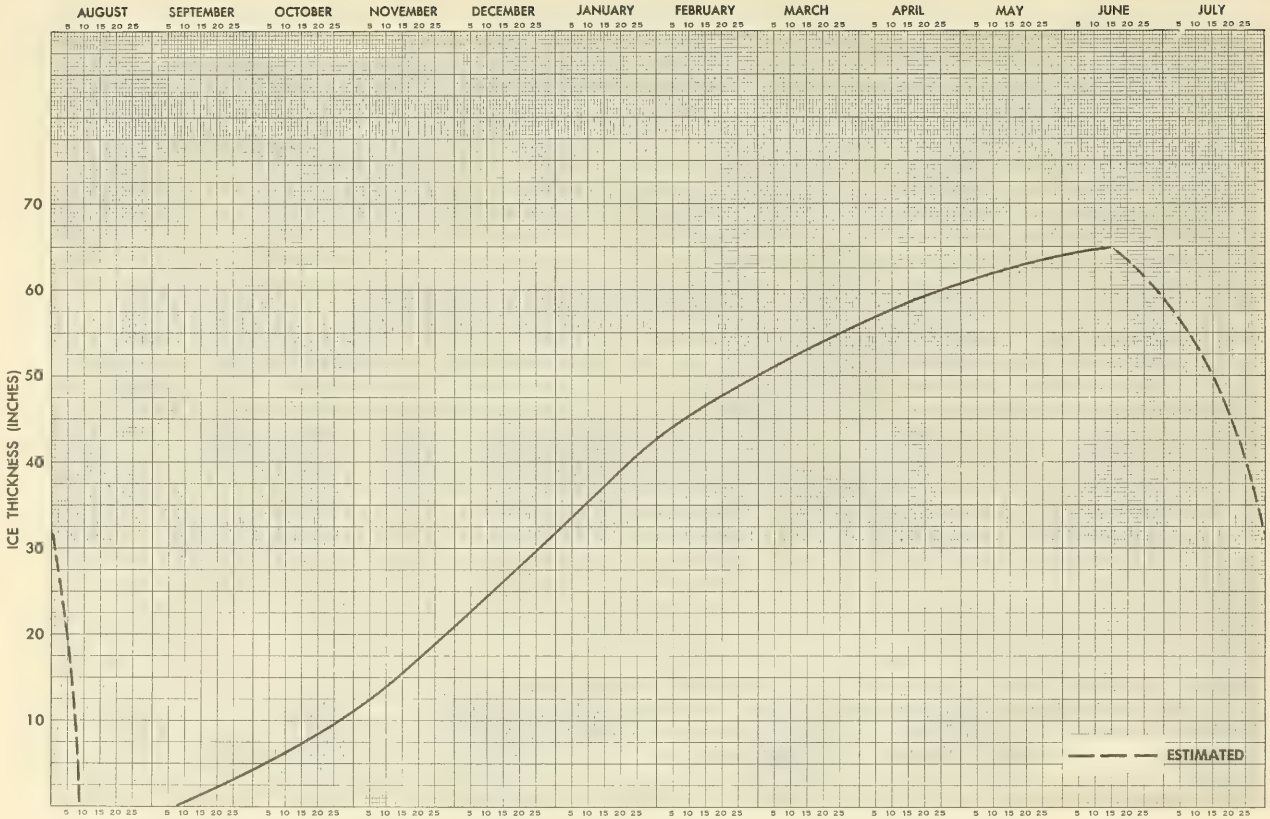

FIGURE 9B WRANGEL ISLAND THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

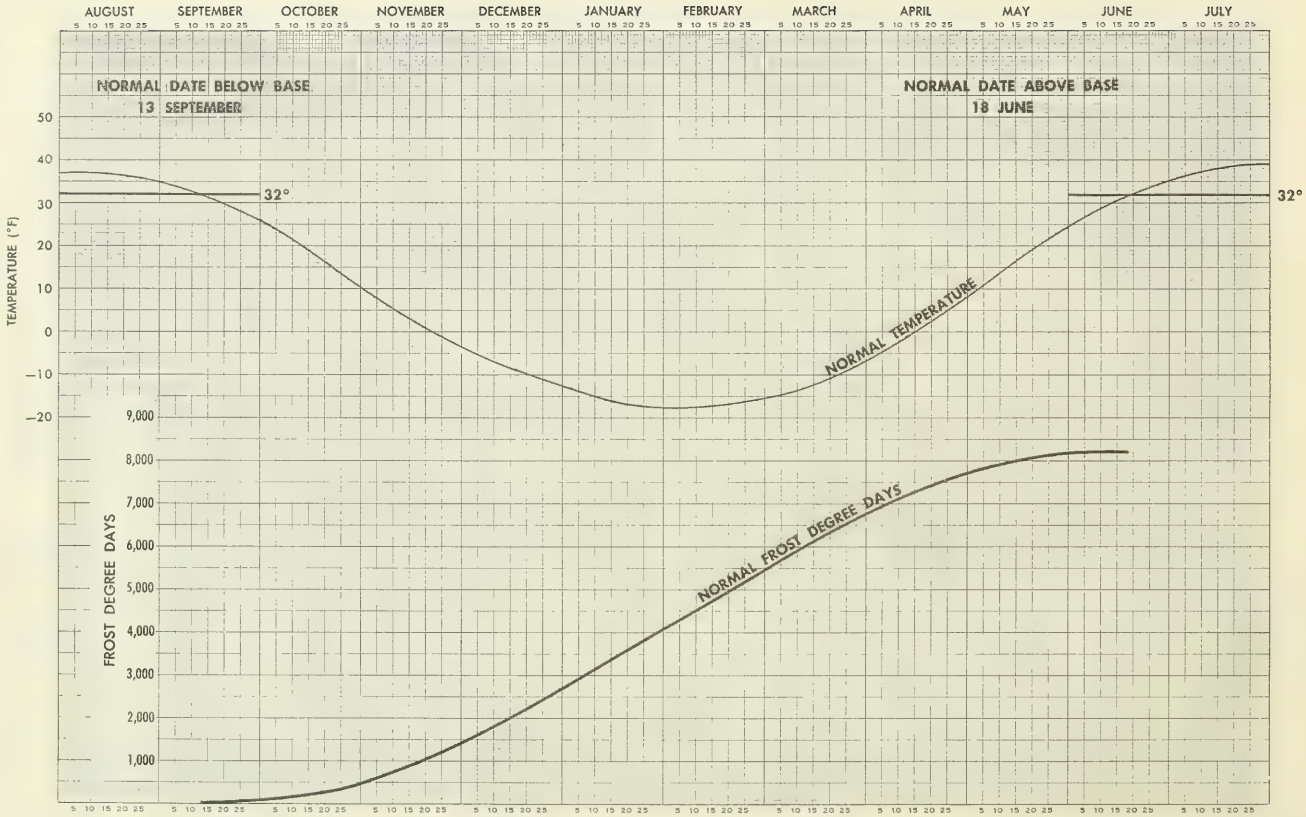

FIGURE 10A MYS SCHMIDTA (9 YEARS RECORD)

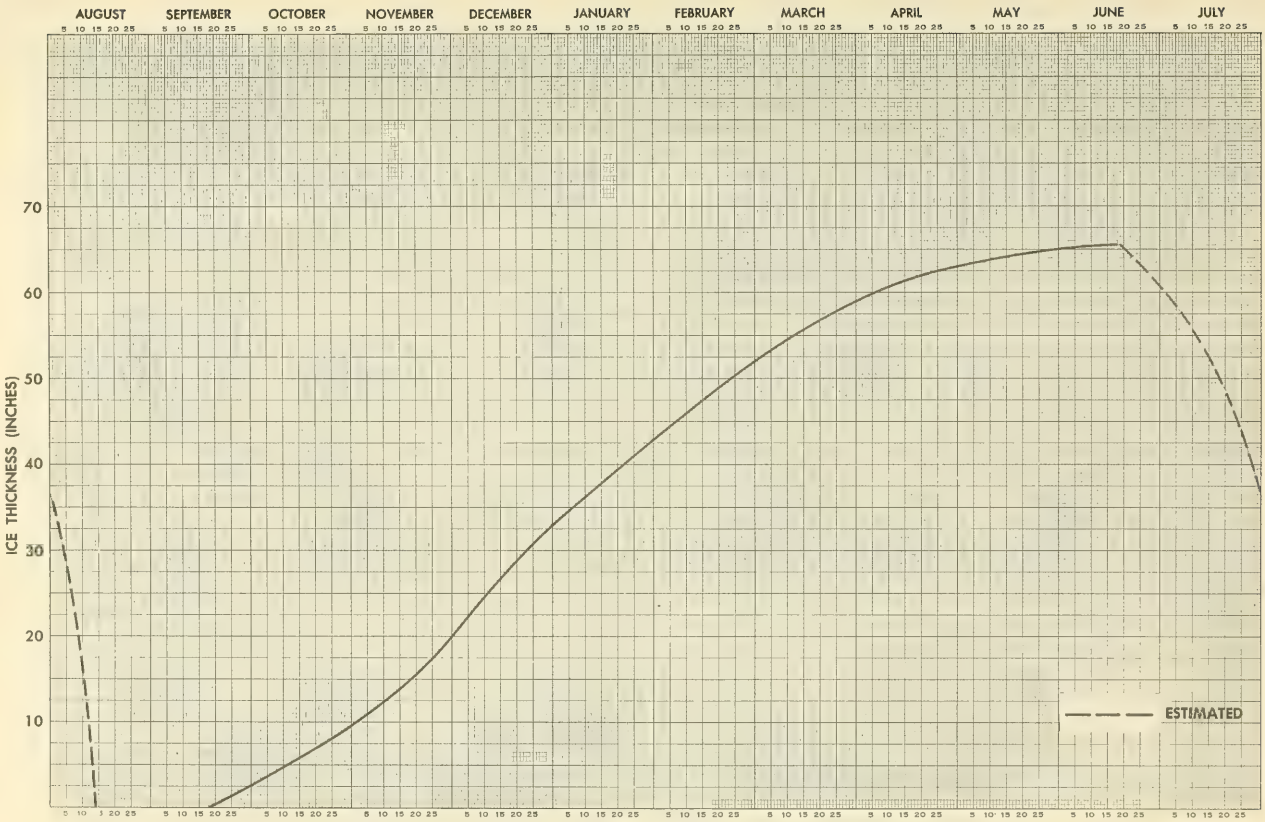

FIGURE 108 MYS SCHMIDTA THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

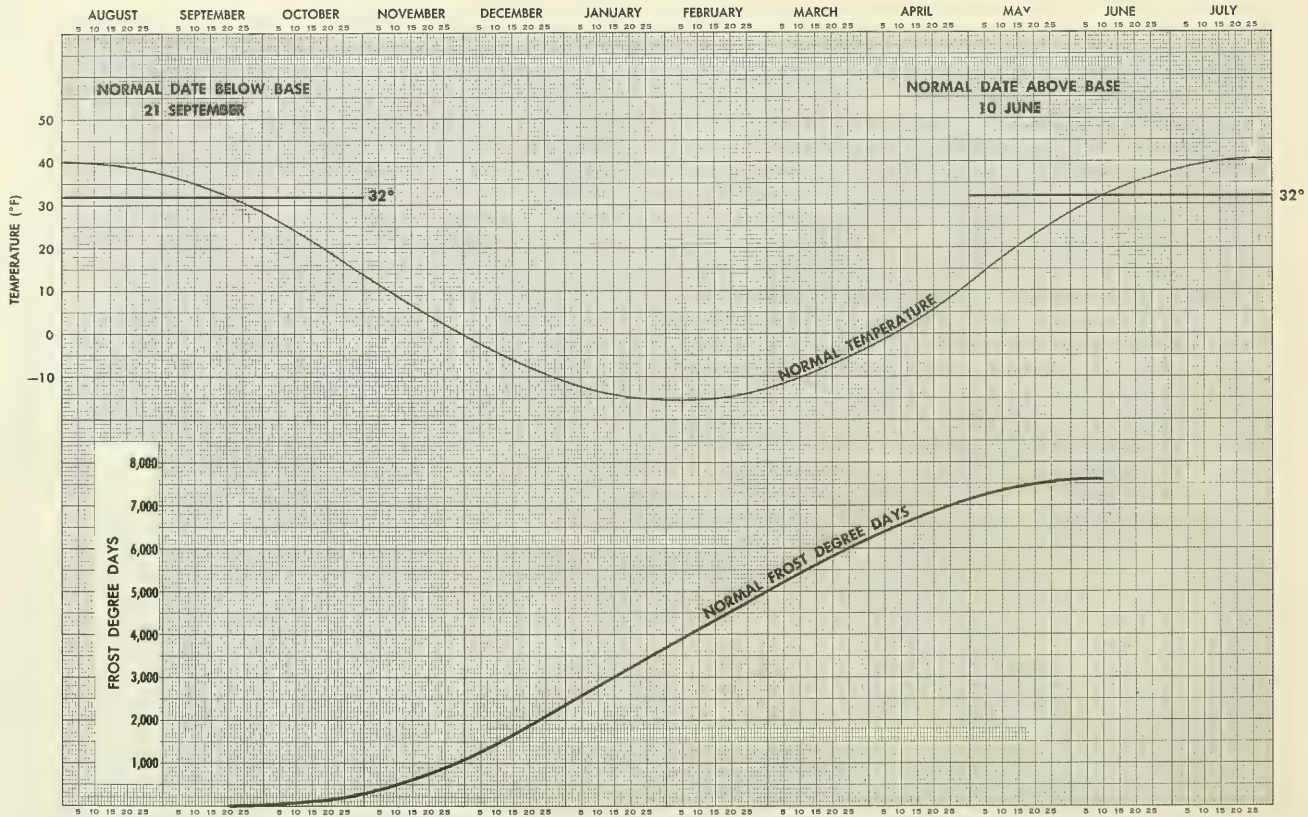

FIGURE 11A MYS VAN KAREM (9 YEARS RECORD)

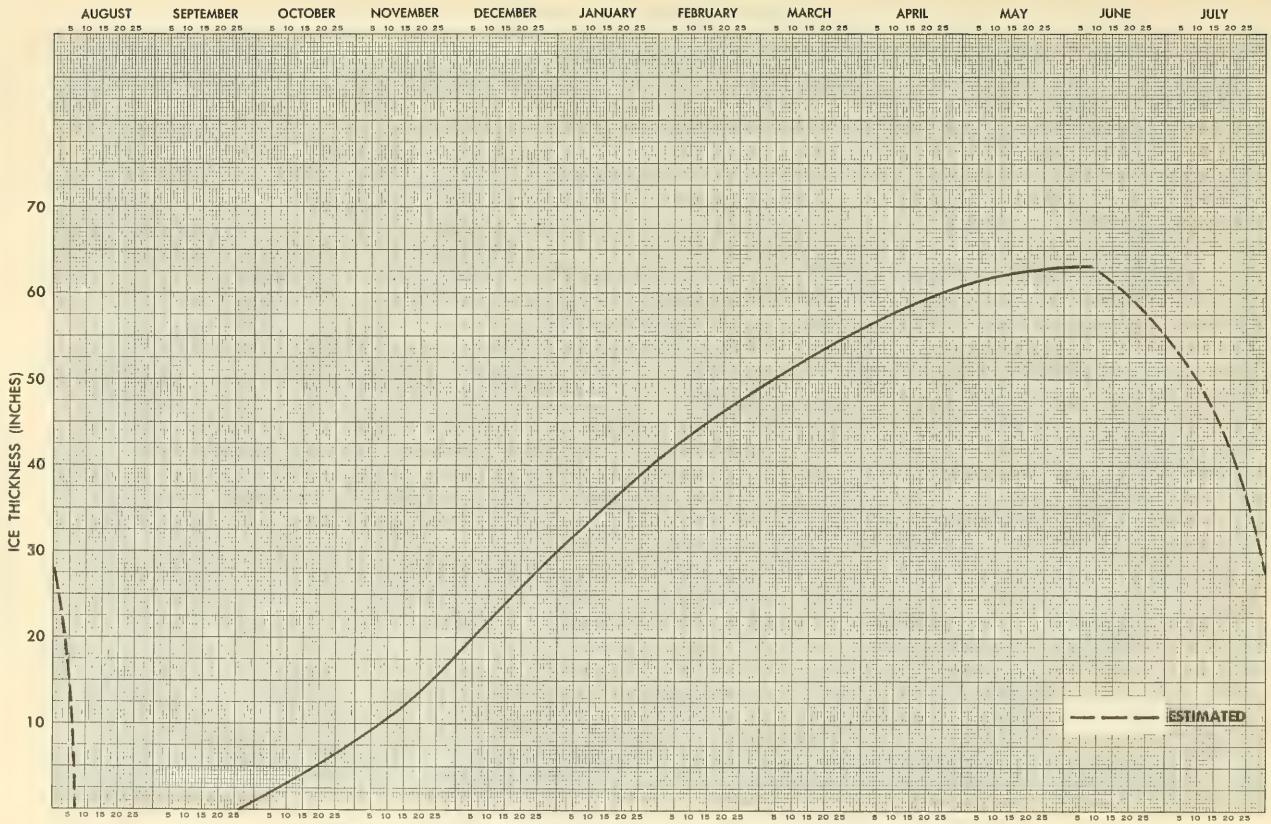

FIGURE 11B MYS VAN KAREM THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

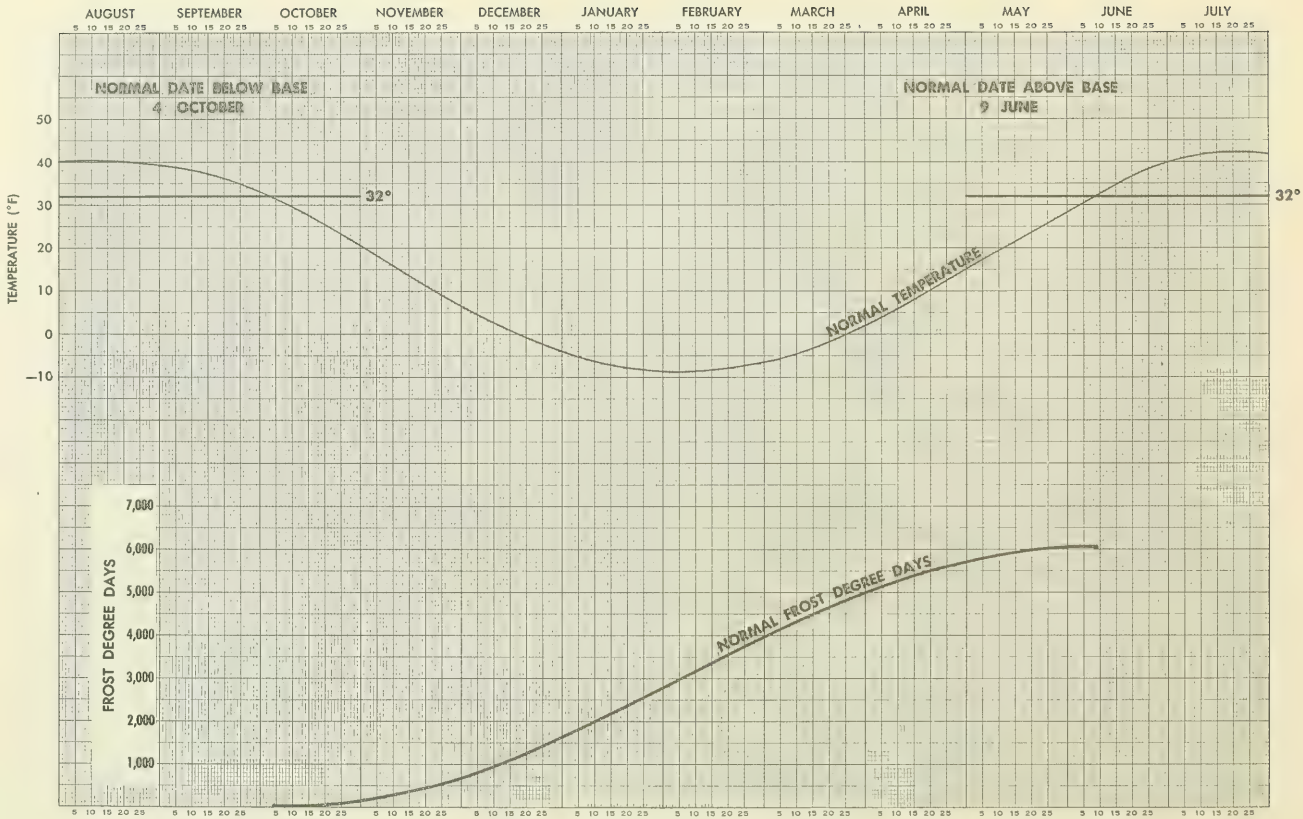

FIGURE 12A MYS DEZHNEVA (9 YEARS RECORD)

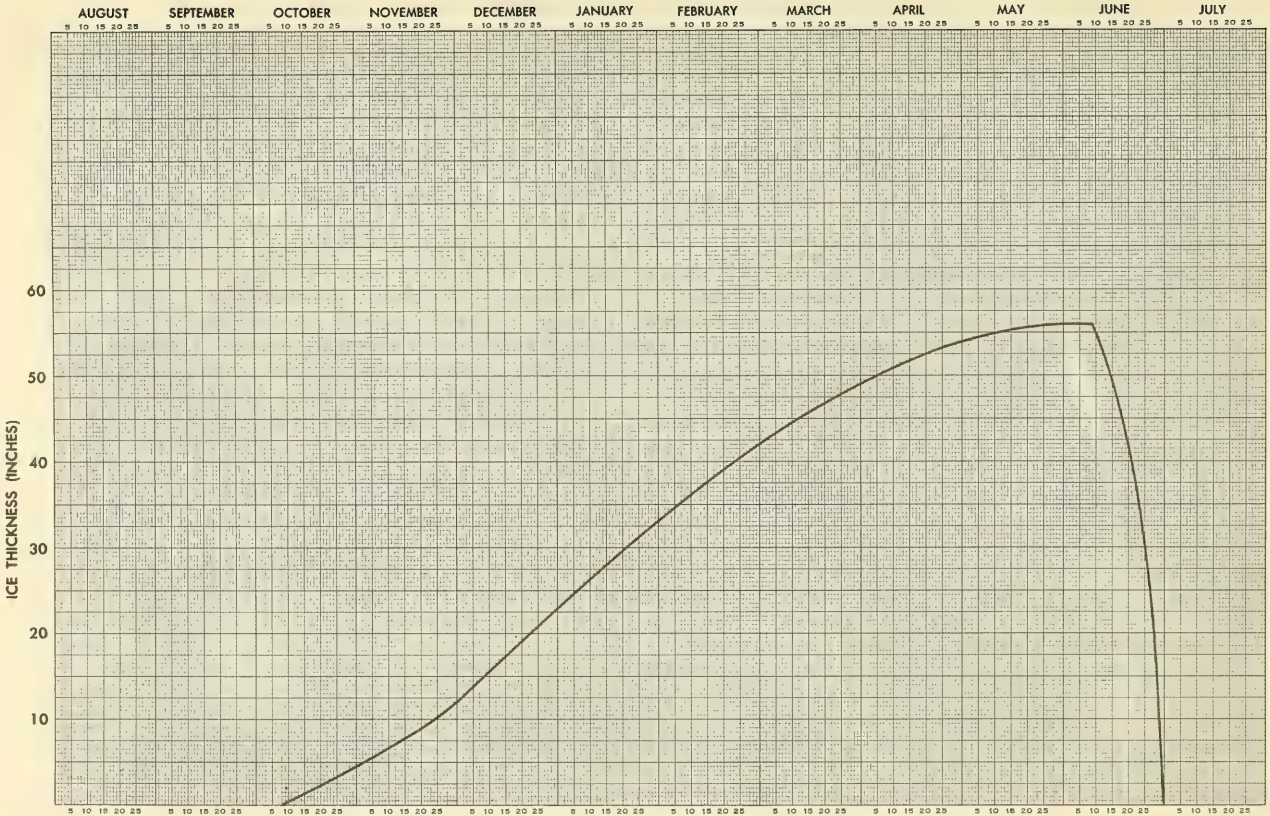

FIGURE 12B MYS DEZHNEVA THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

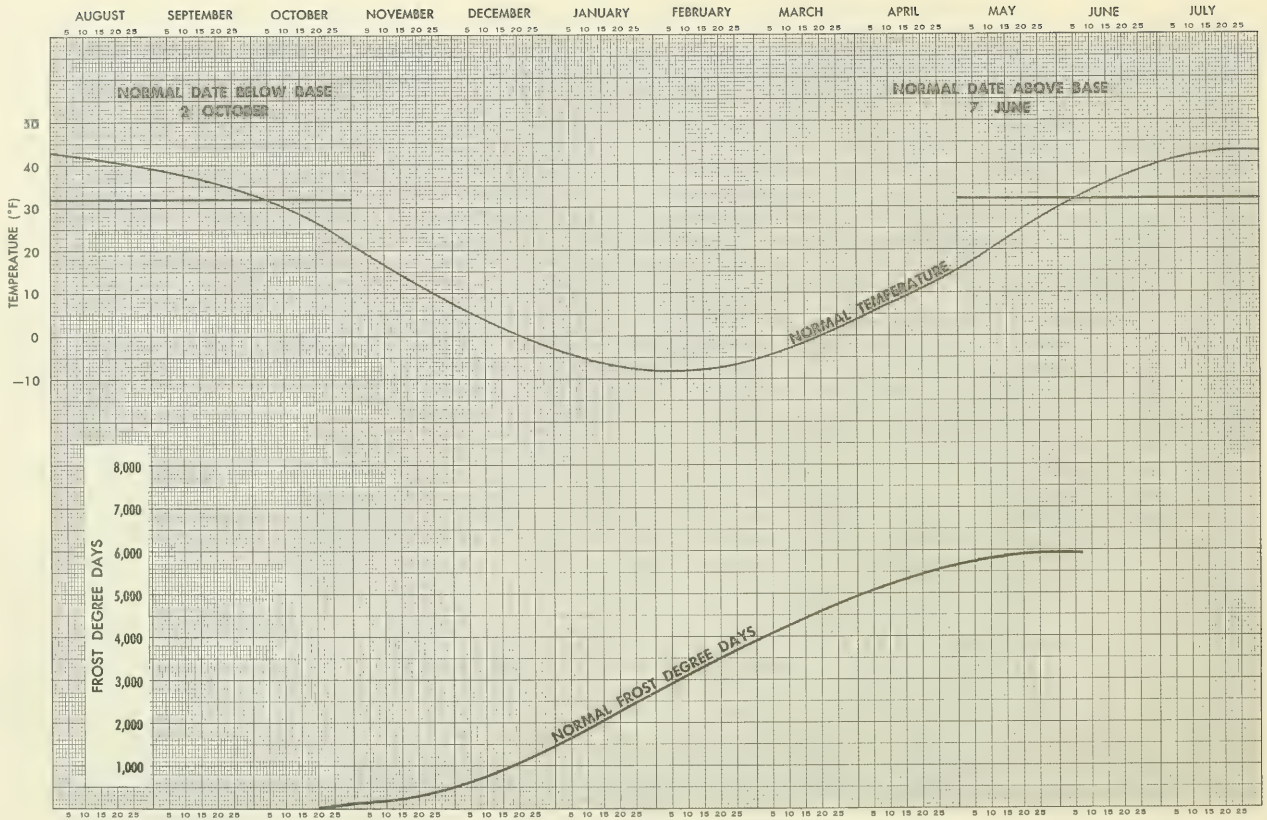

FIGURE 13A UELEN (9 YEARS RECORD)

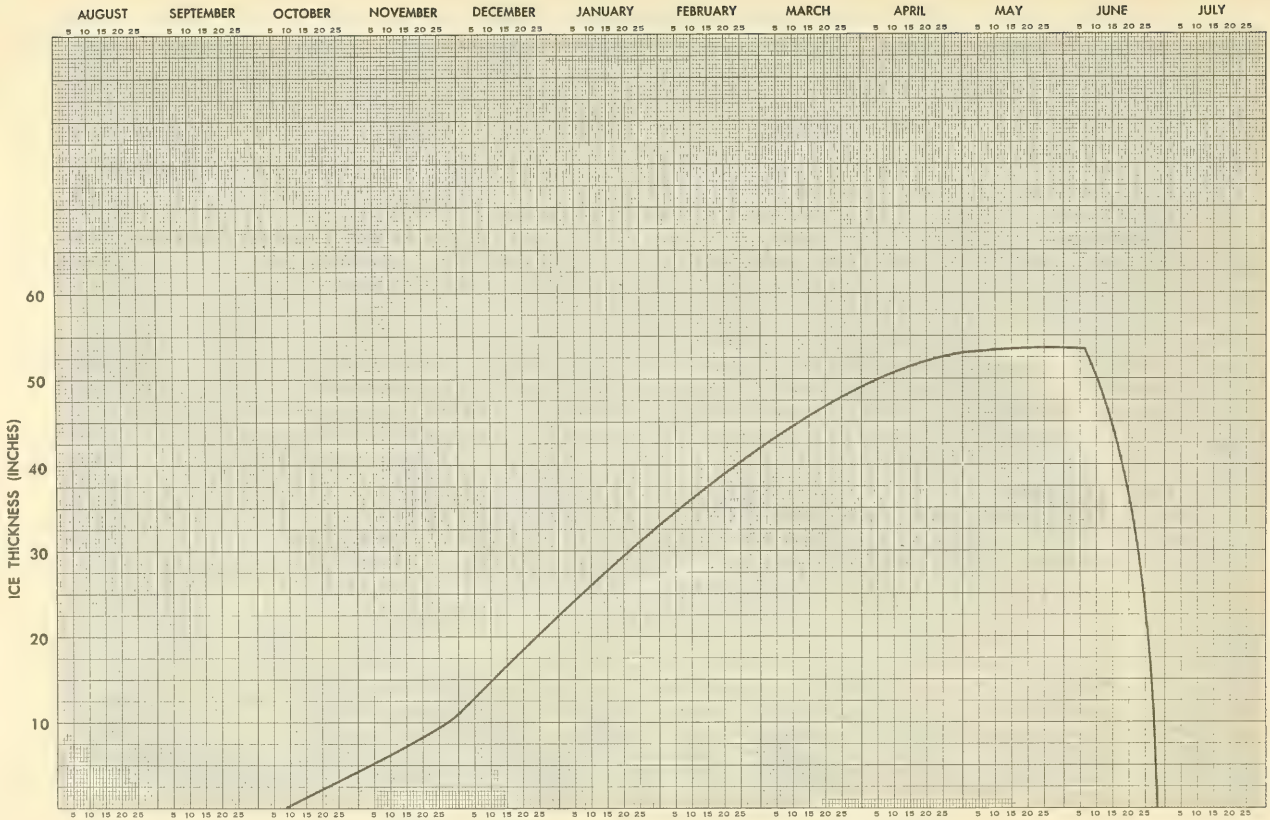

FIGURE 13B UELEN THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

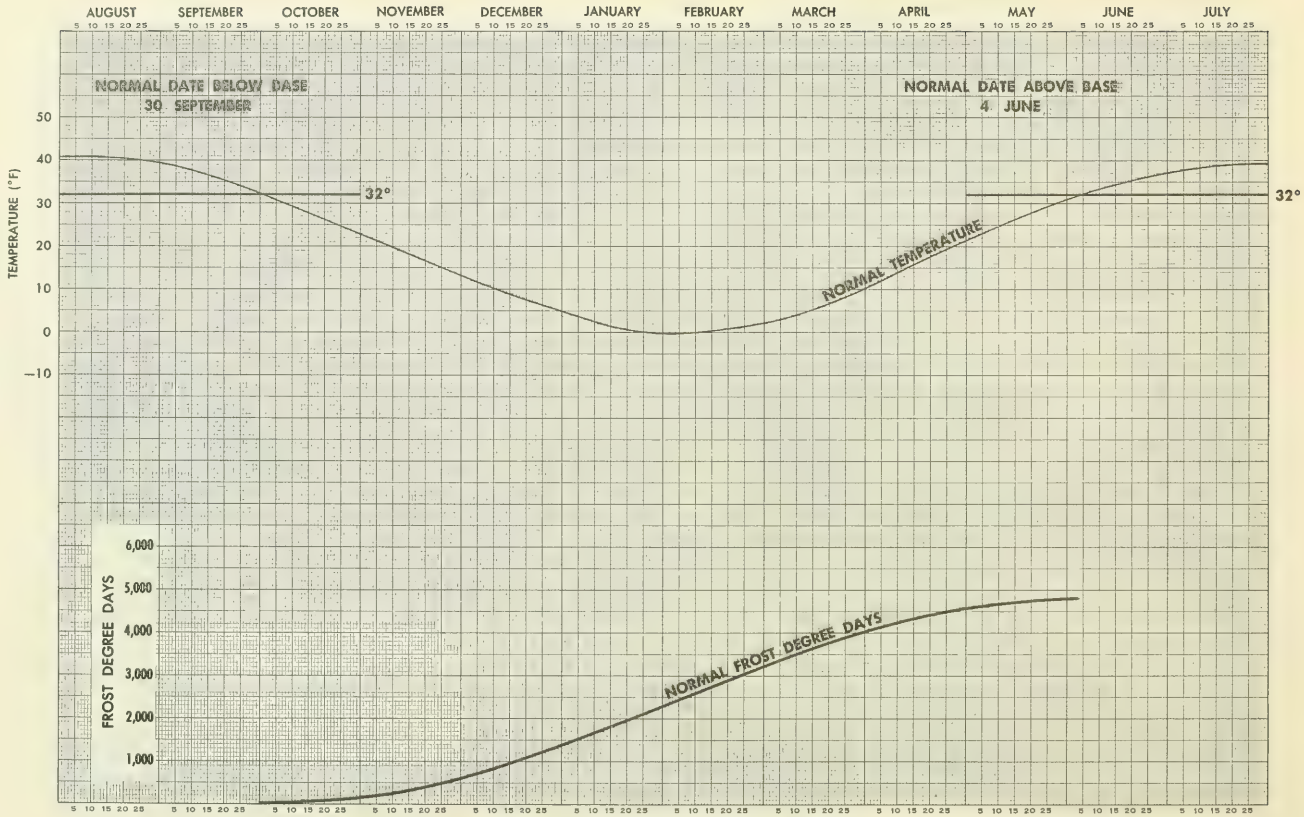

FIGURE 14A MYS CHAPLINA (9 YEARS RECORD)

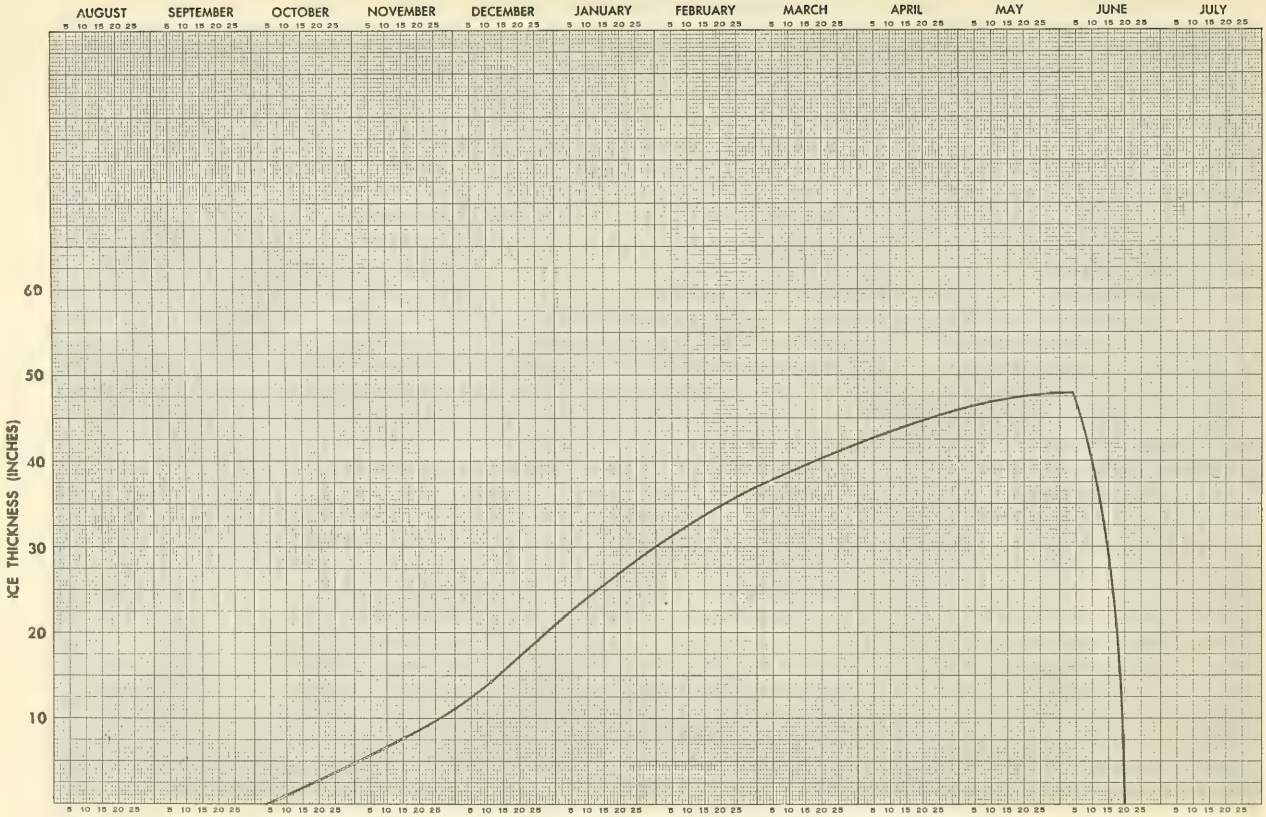

FIGURE 14B MYS CHAPLINA THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

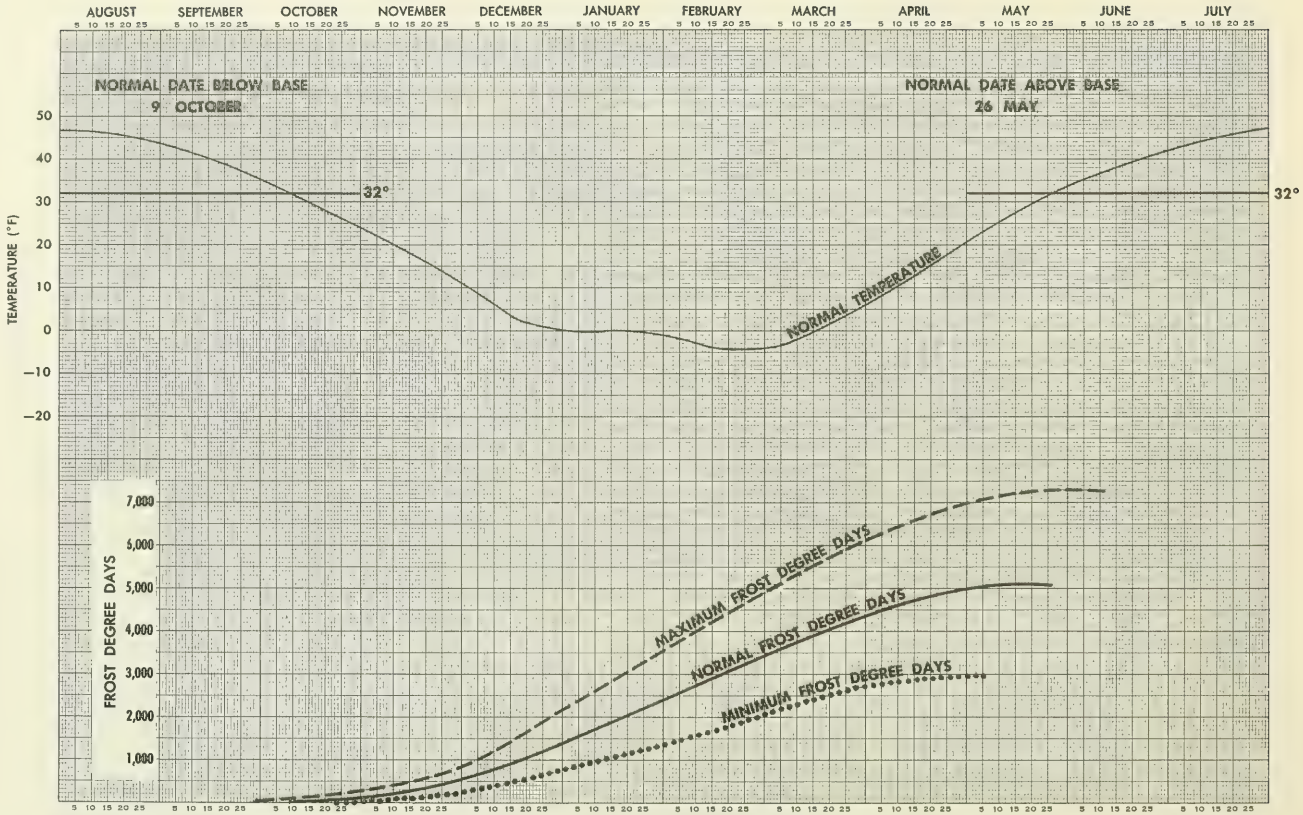

FIGURE 15A WALES (12 YEARS RECORD)

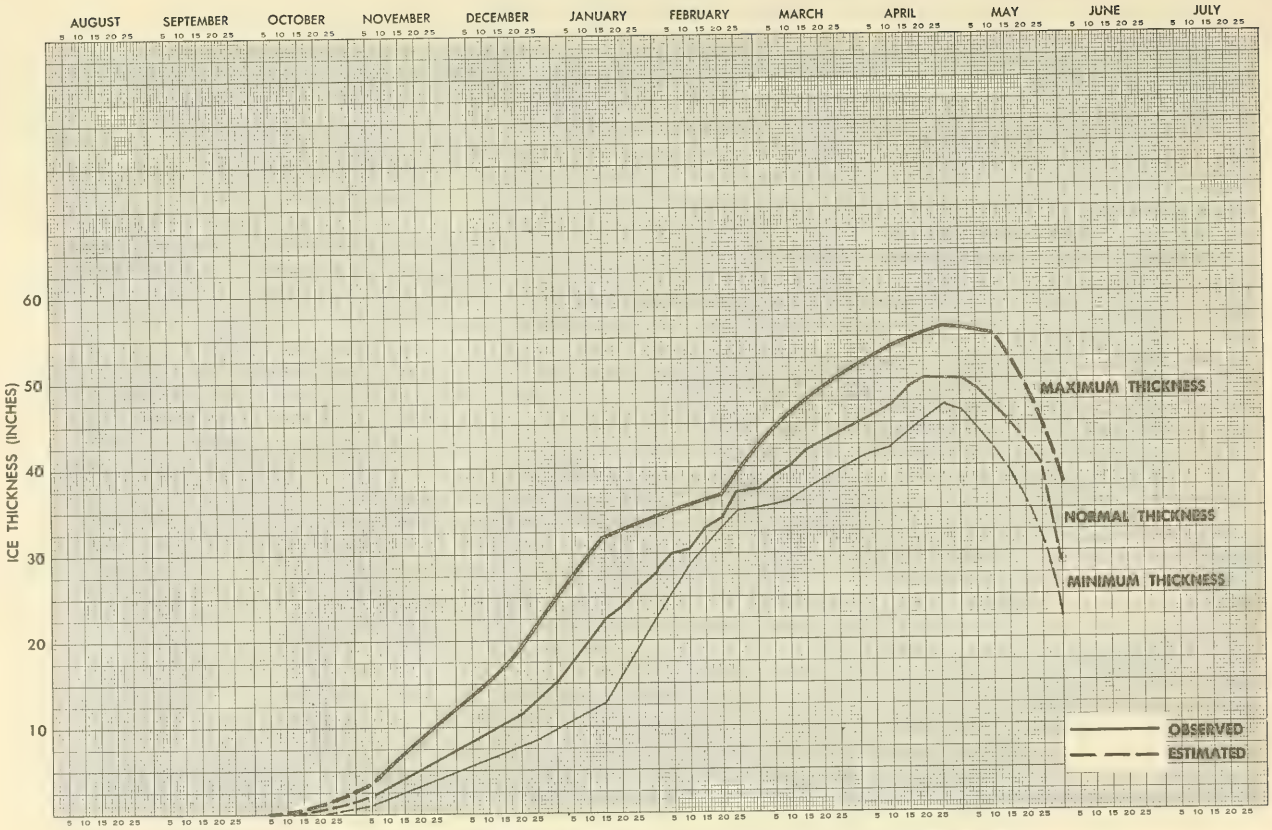

FIGURE 15B WALES EMPIRICAL ICE GROWTH AND DISINTEGRATION CURVE (3 YEARS RECORD)

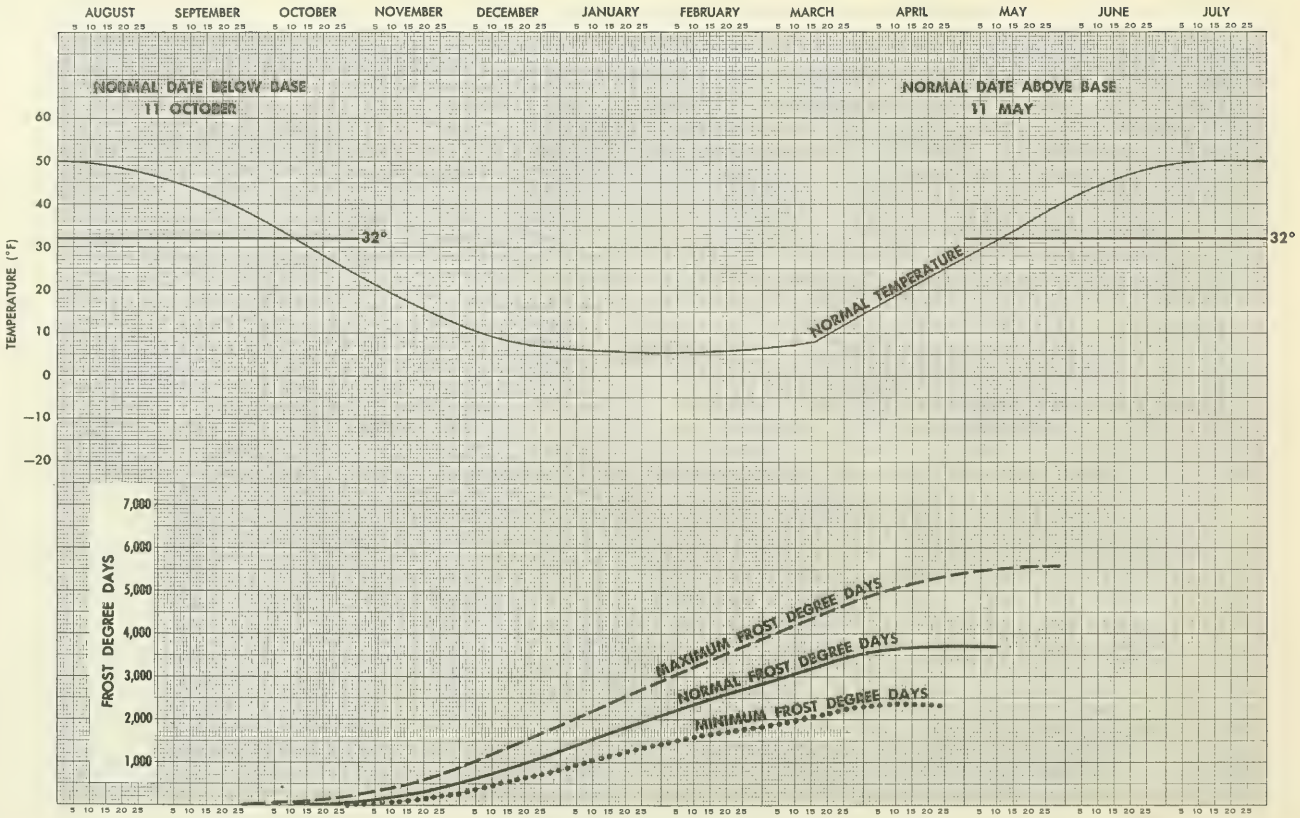

FIGURE 16A NOME (30 YEARS RECORD)

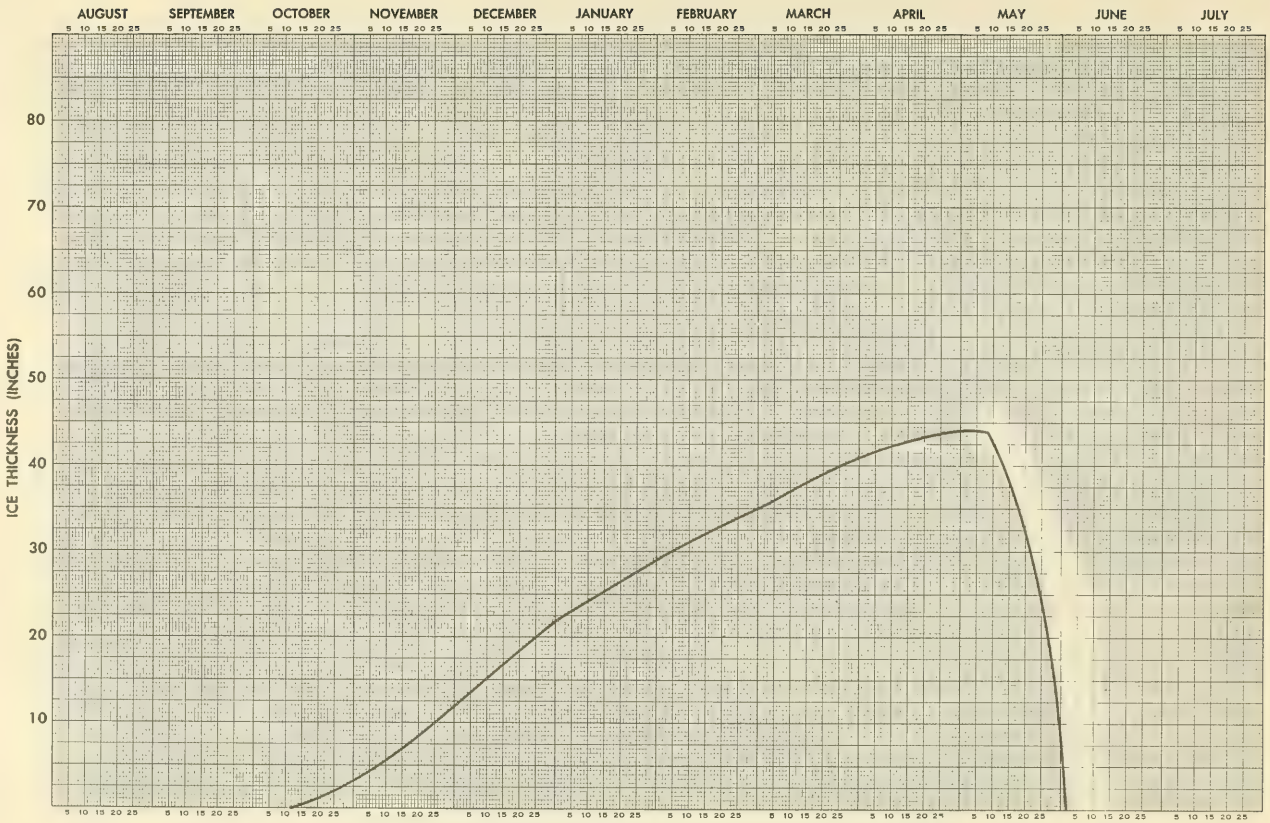

FIGURE 16B NOME THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

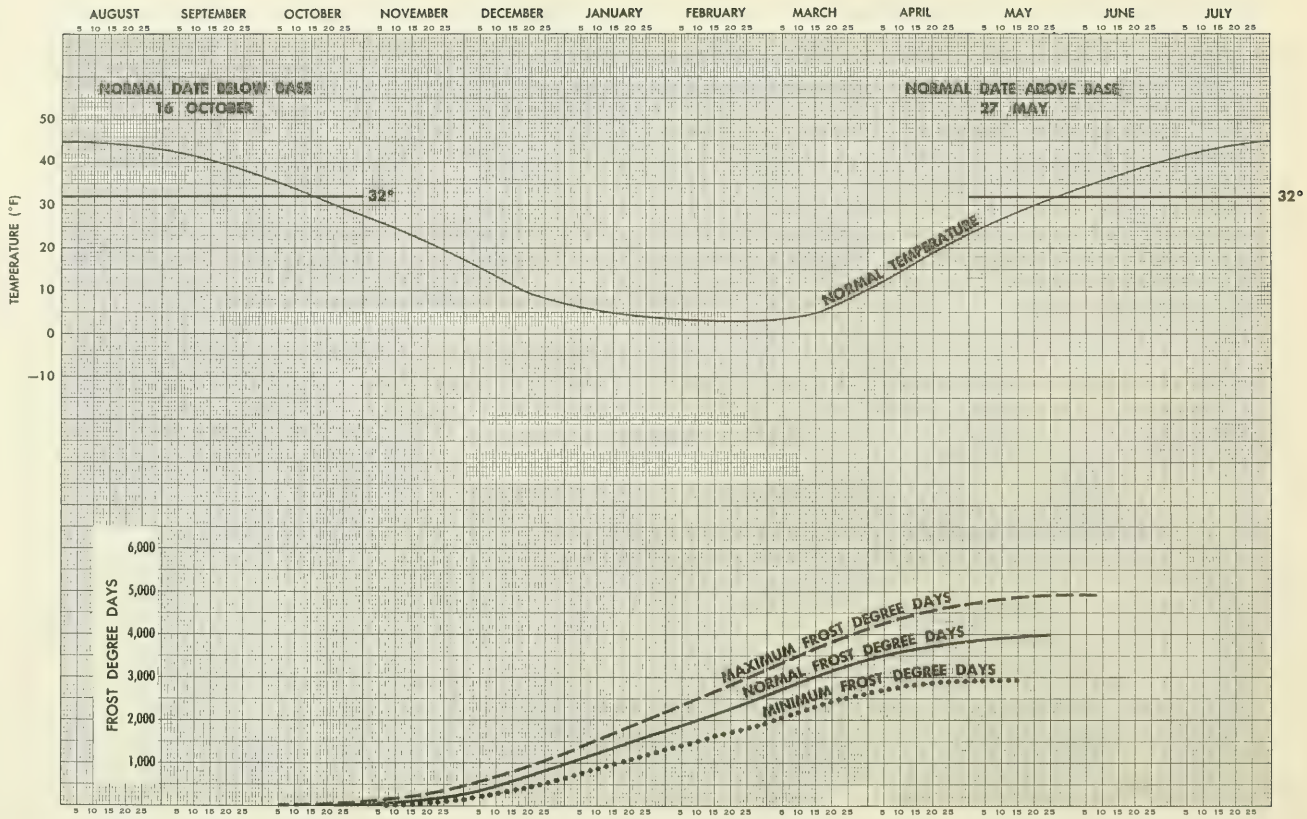

FIGURE 17A GAMBELL (10 YEARS RECORD)

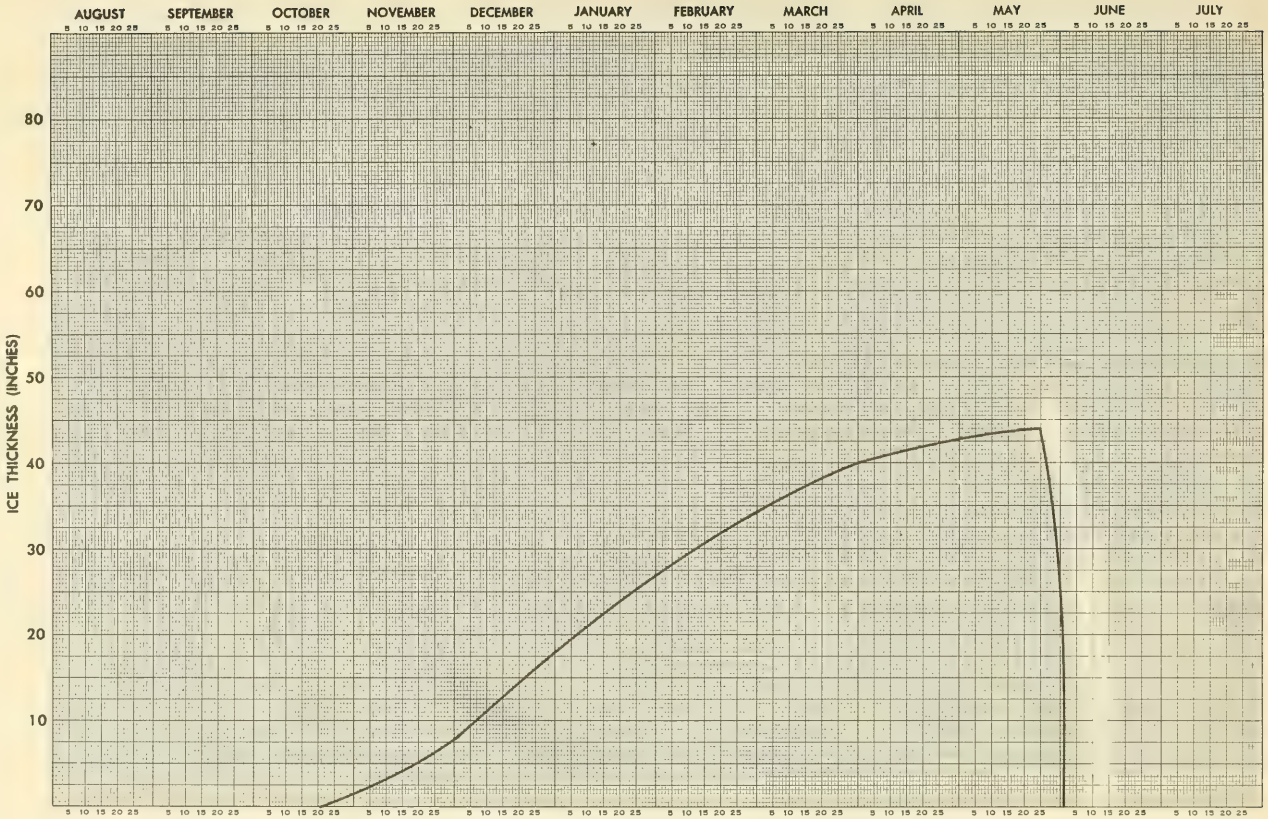

FIGURE 17B GAMBELL THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

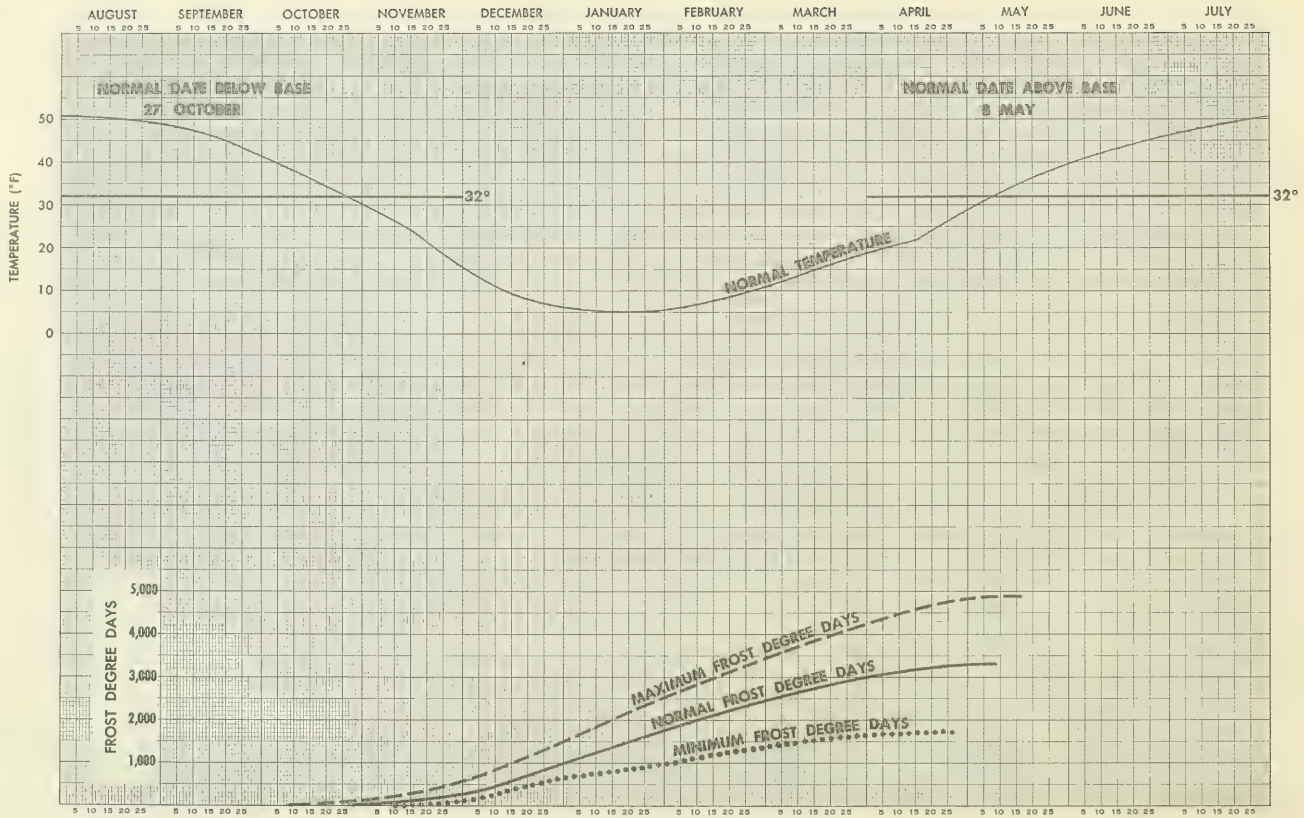

FIGURE 18A NUNIVAK (9 YEARS RECORD)

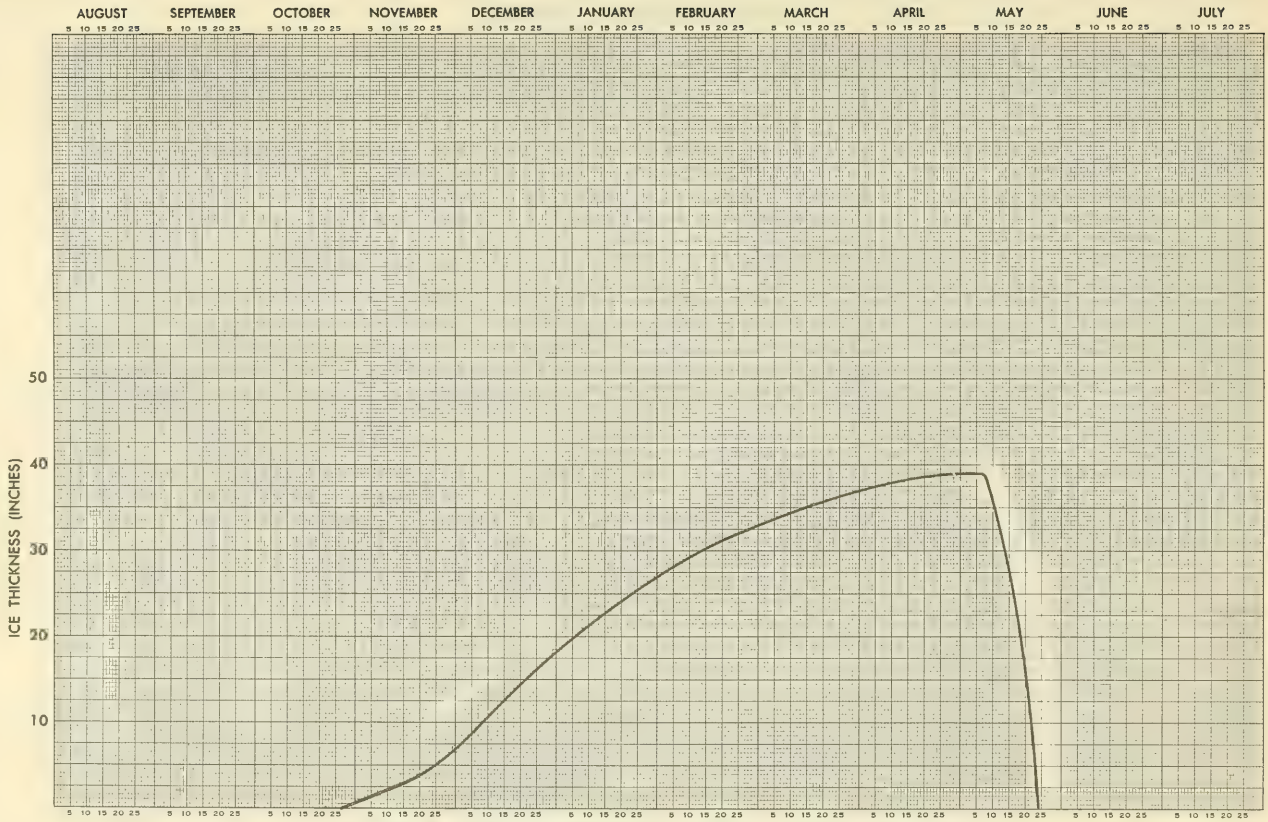

FIGURE 18B NUNIVAK THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

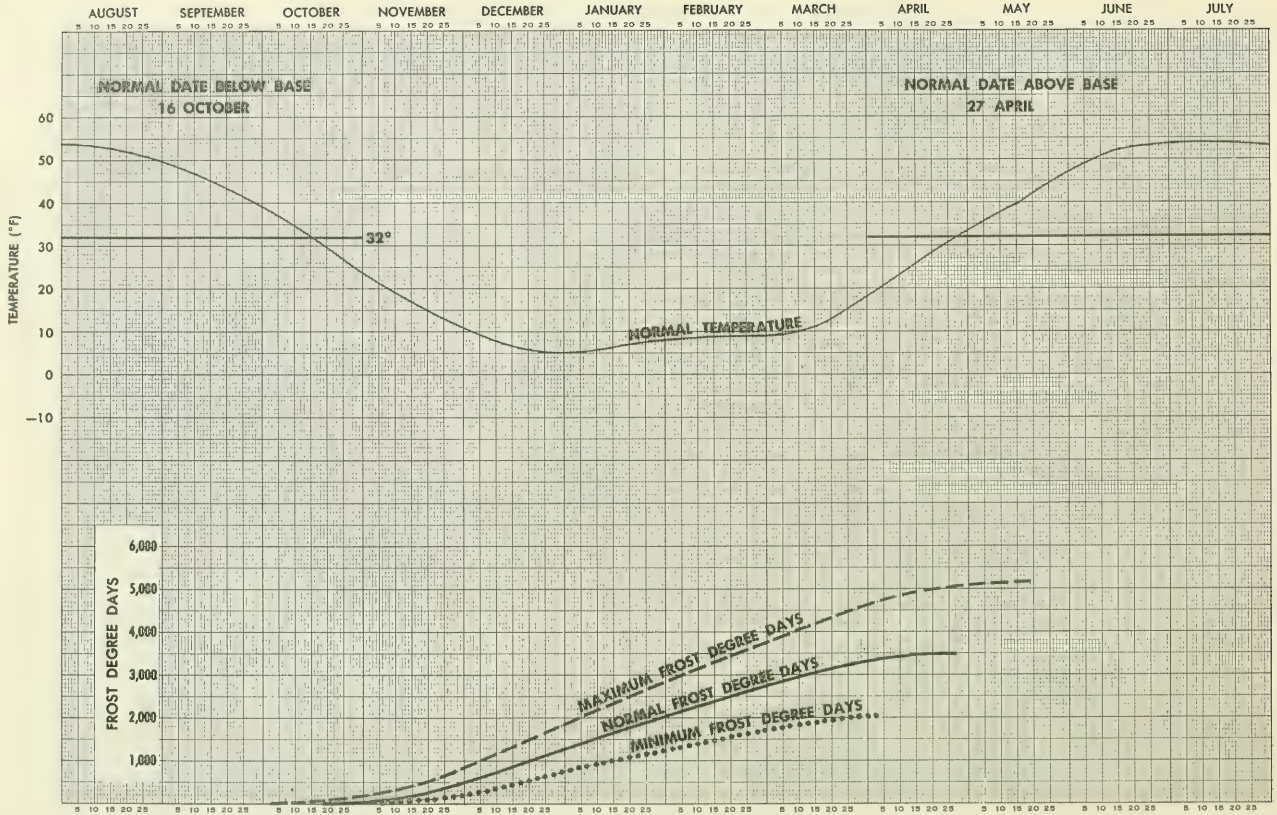

FIGURE 19A BETHEL (30 YEARS RECORD)

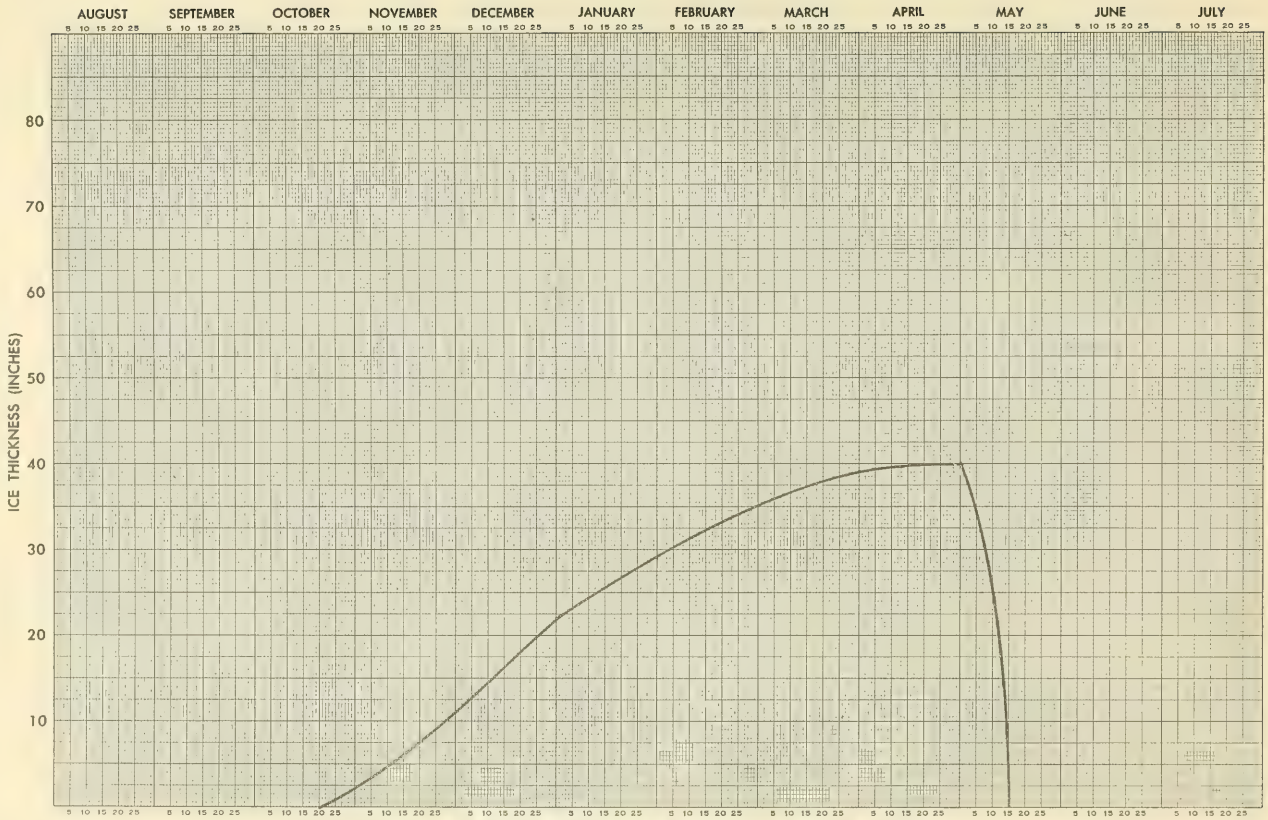

FIGURE 19B BETHEL THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

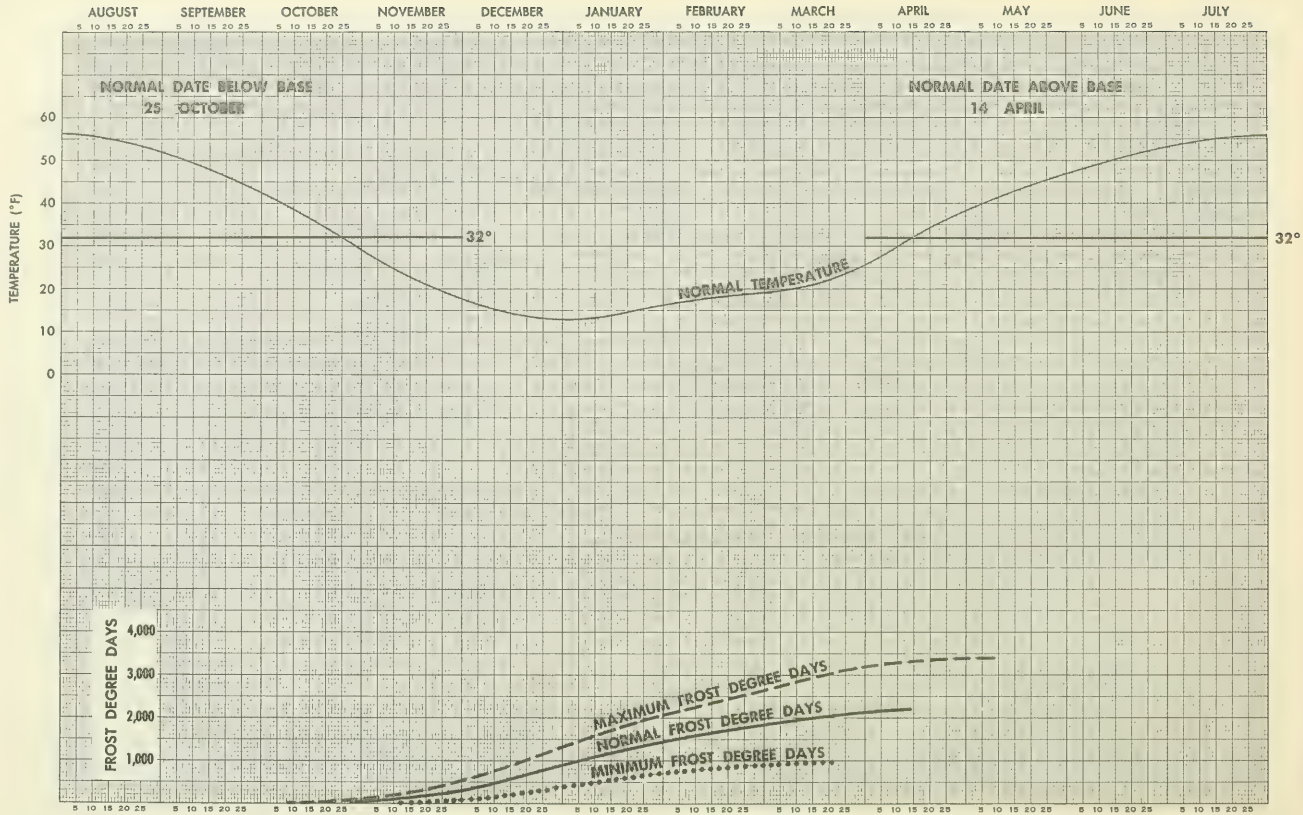

FIGURE 20A NAKNEK (30 YEARS RECORD)

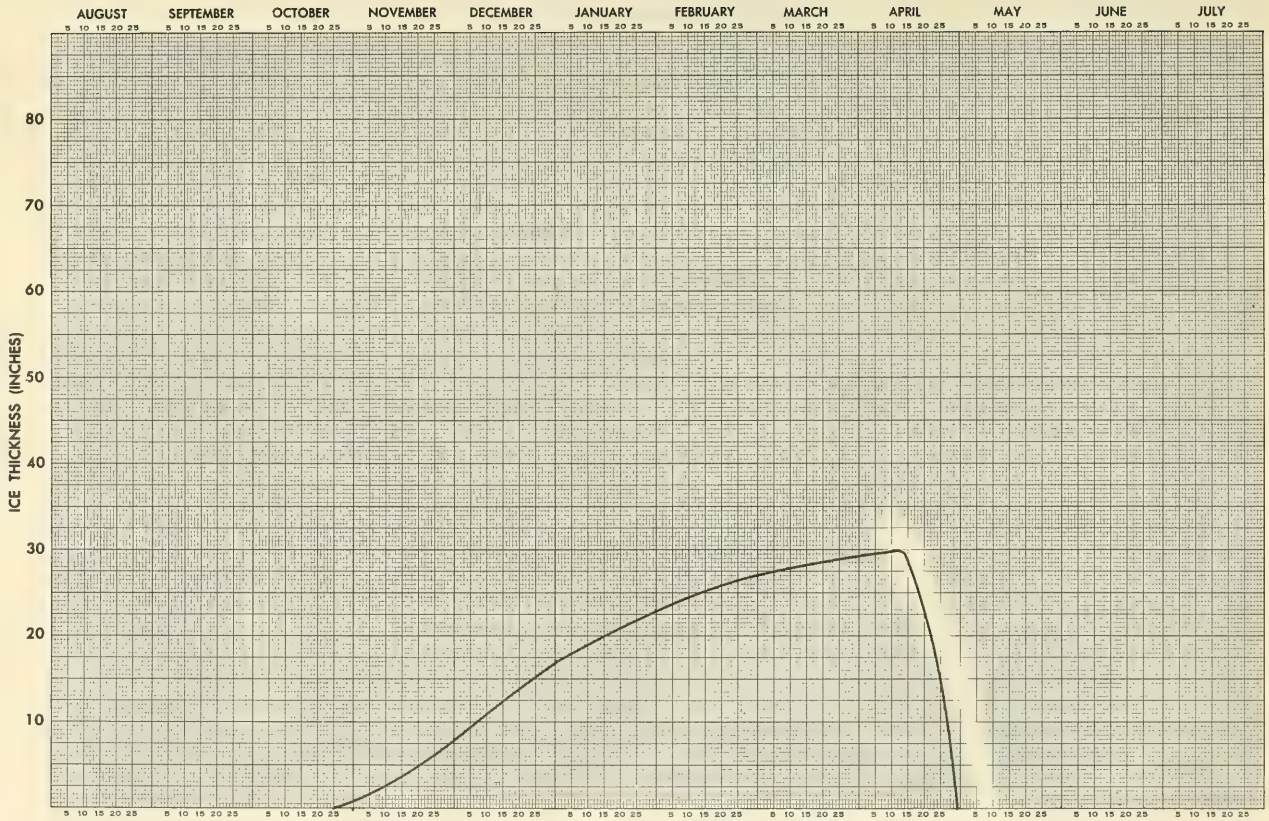

FIGURE 20B NAKNEK THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

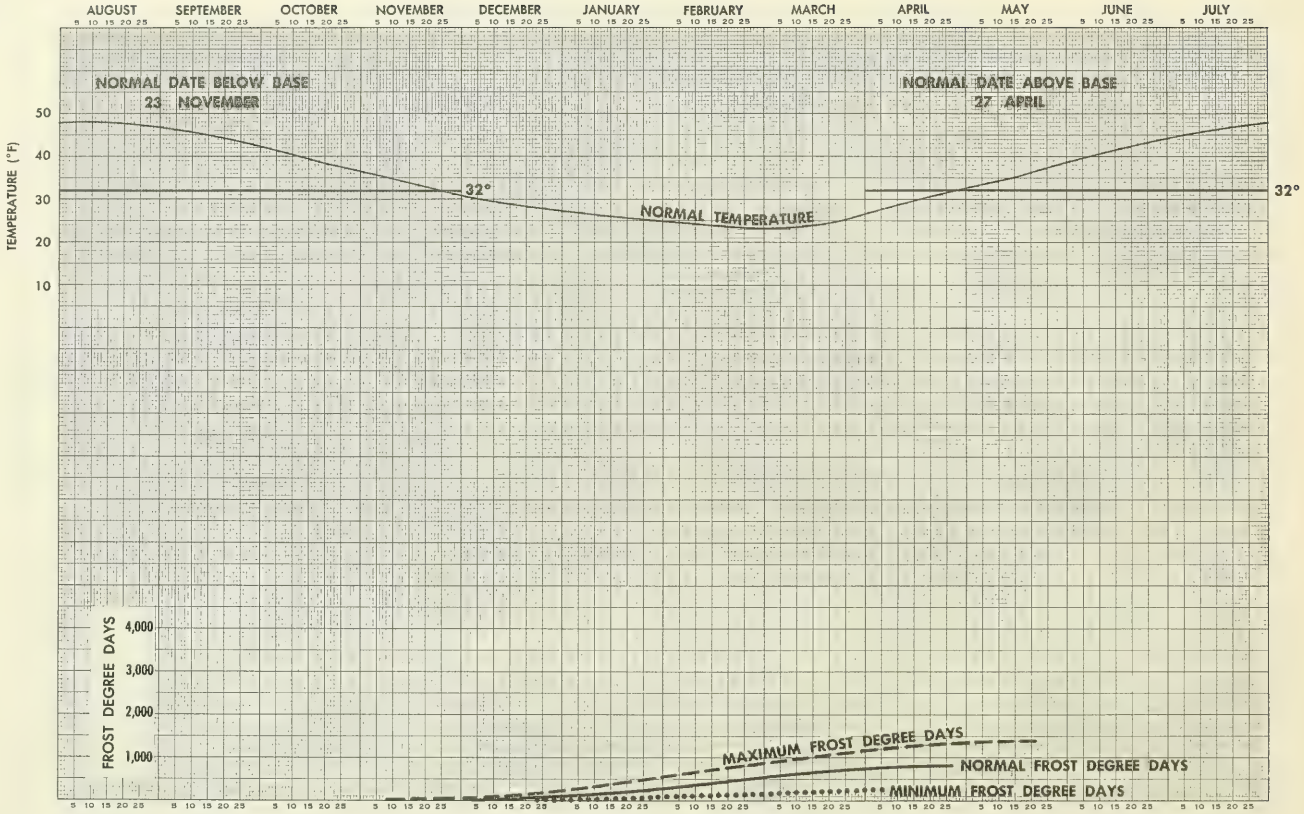

FIGURE 21A ST PAUL ISLAND (30 YEARS RECORD)

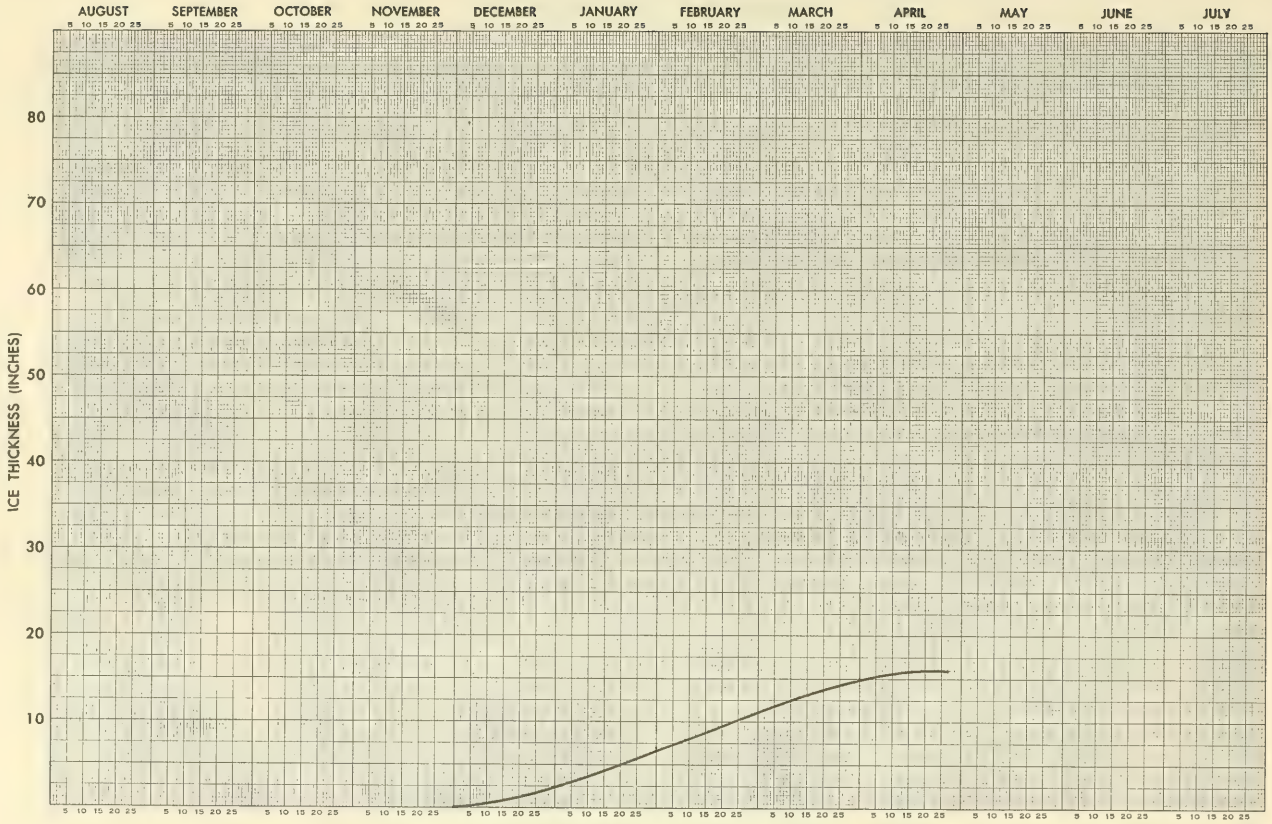

FIGURE 21B ST PAUL ISLAND ICE GROWTH CURVE

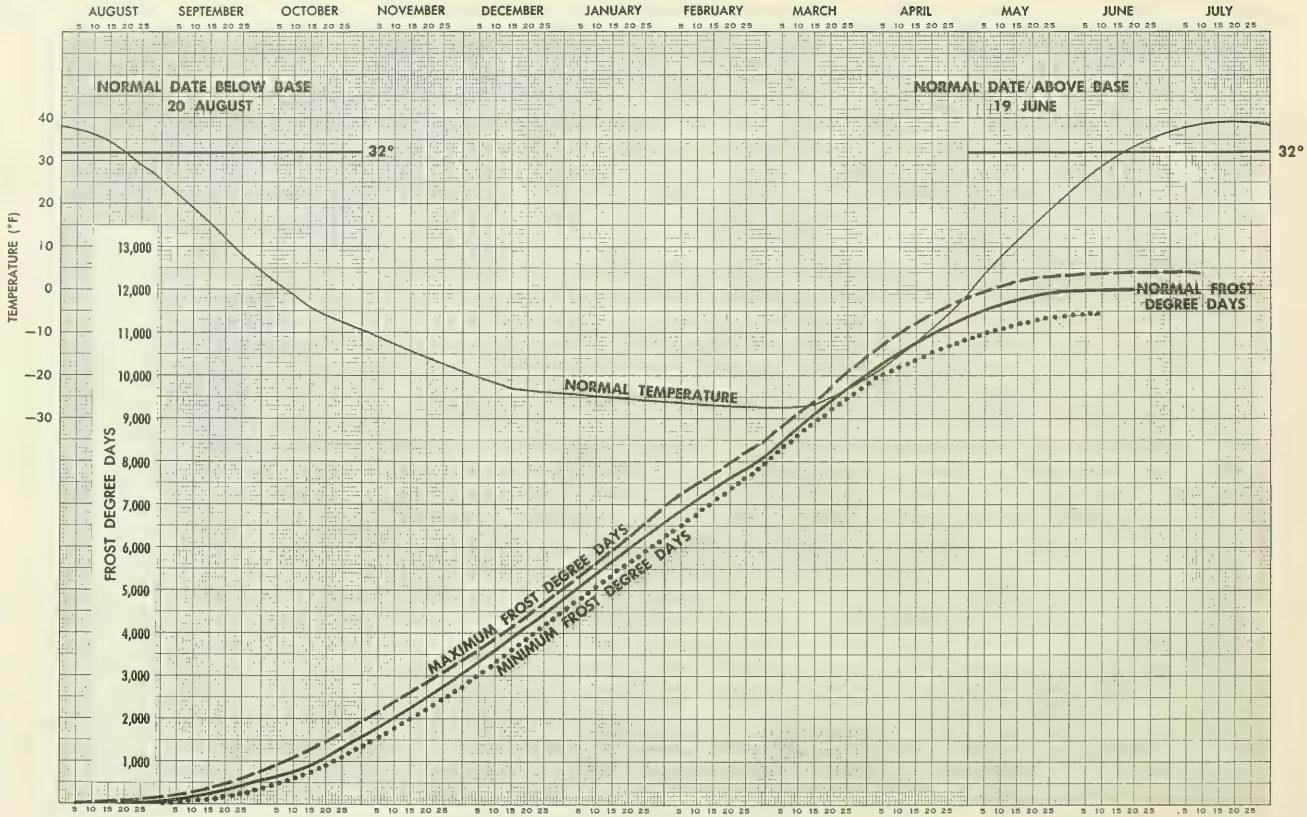

FIGURE 22A ALERT (11 YEARS RECORD)

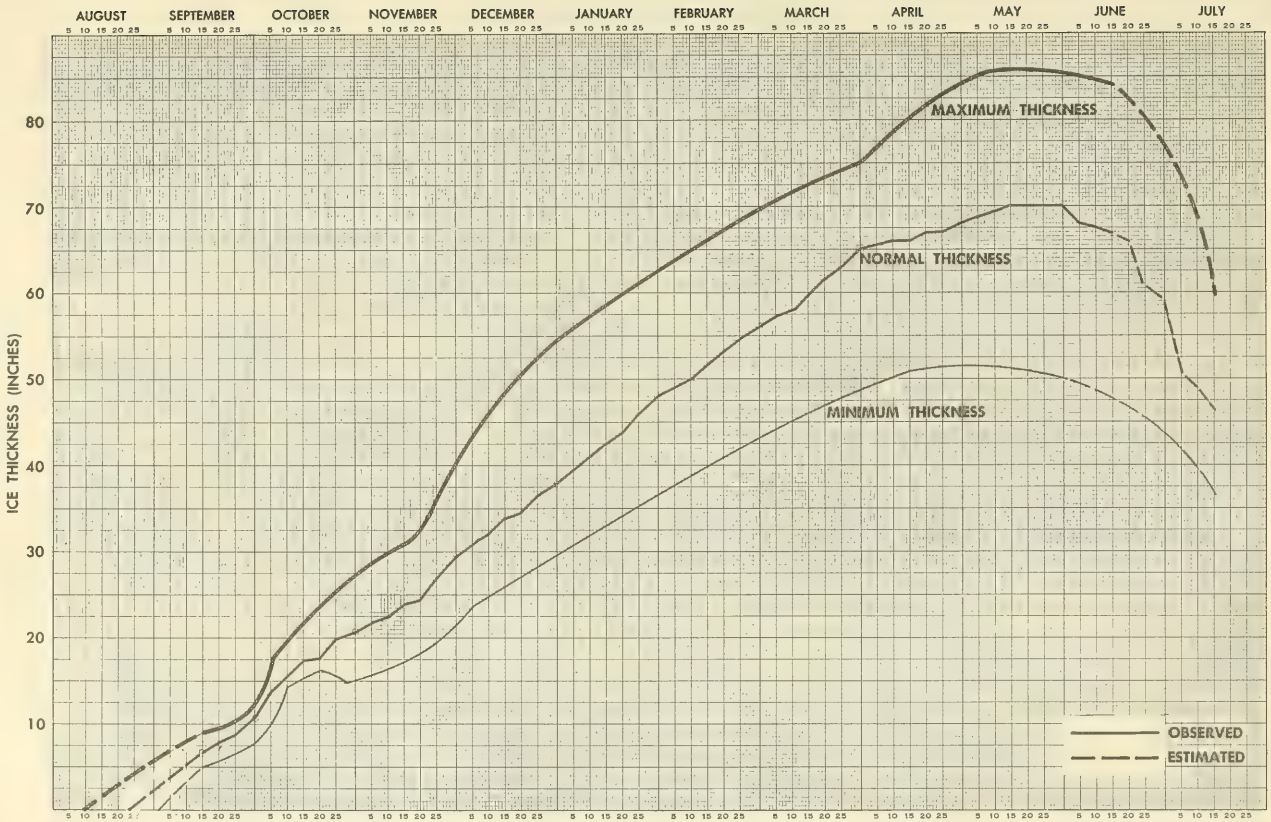

FIGURE 22B ALERT EMPIRICAL ICE GROWTH AND DISINTEGRATION CURVE (10 YEARS RECORD)

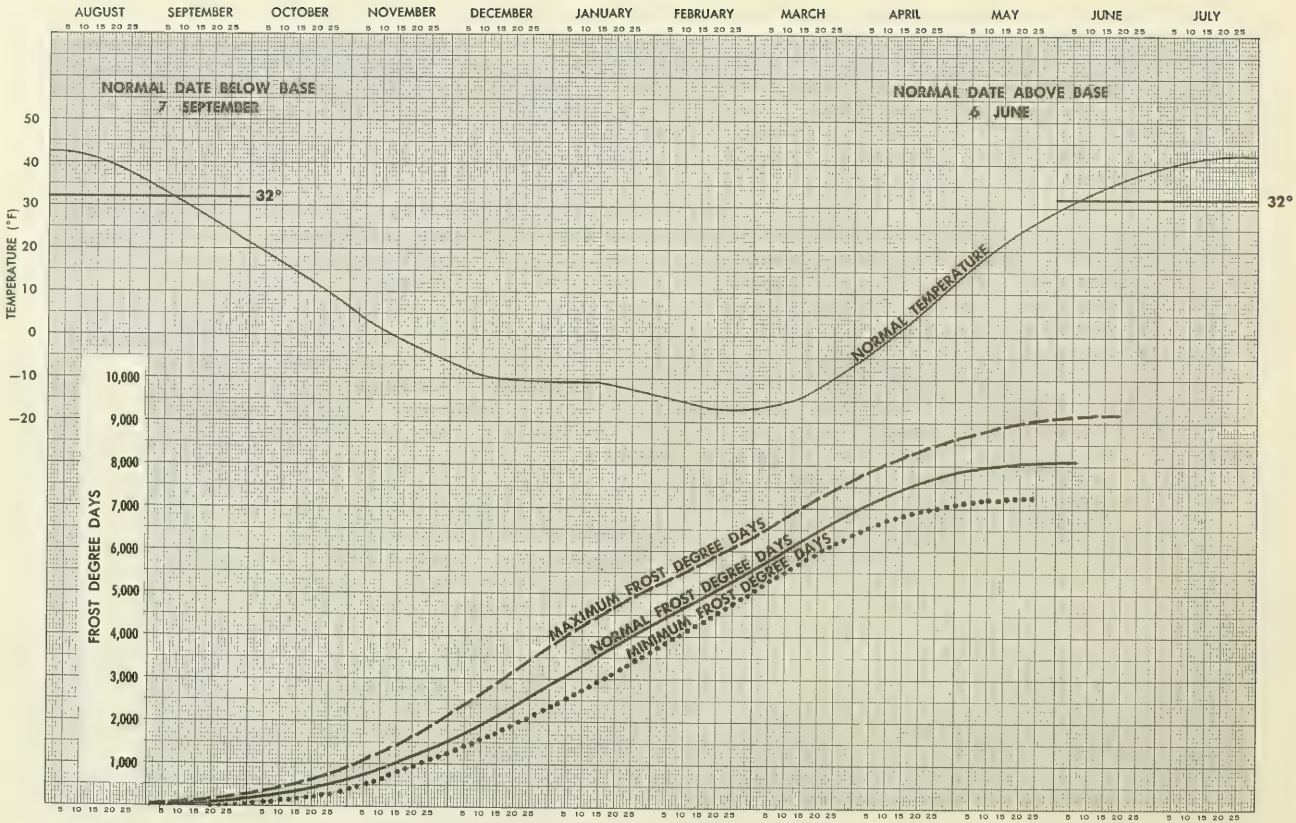

FIGURE 23A THULE (6 YEARS RECORD)

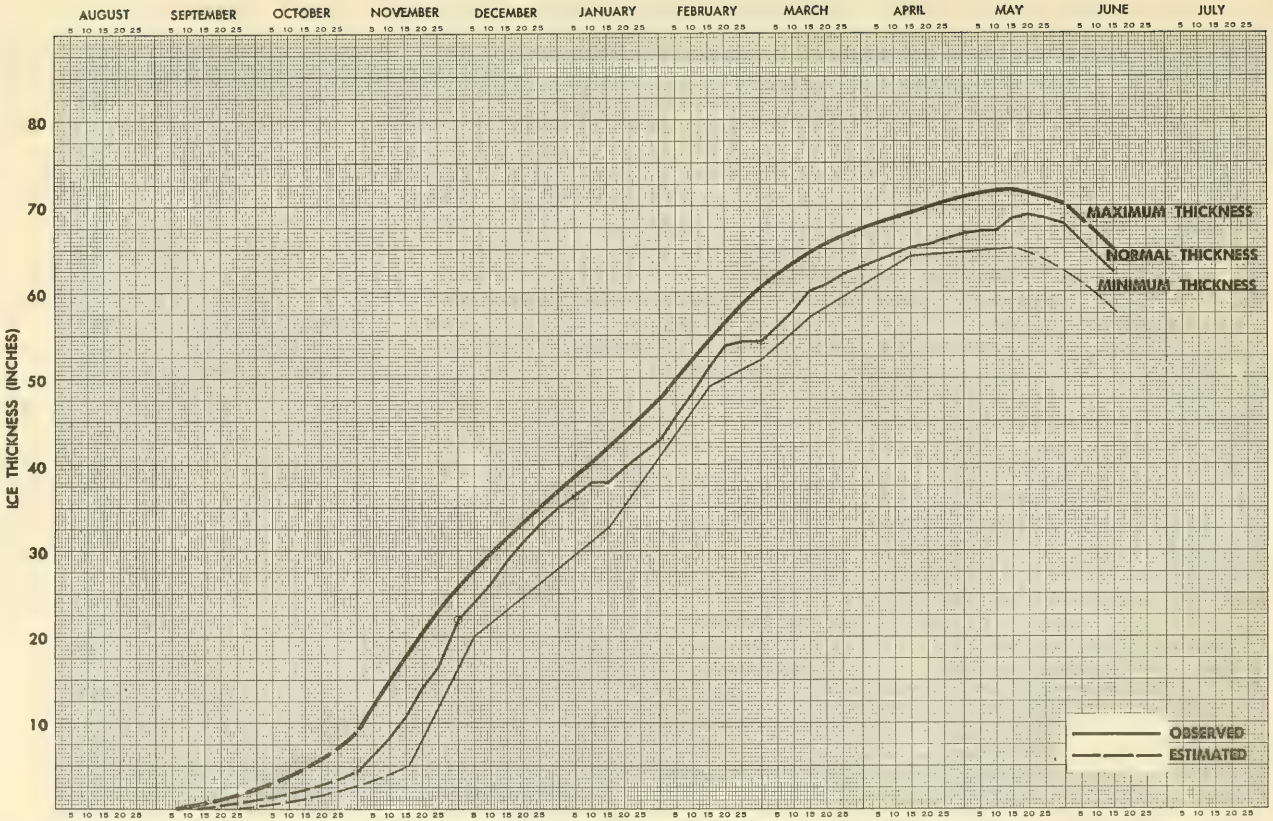

FIGURE 23B THULE EMPIRICAL ICE GROWTH AND DISINTEGRATION CURVE (*5* YEARS RECORD)

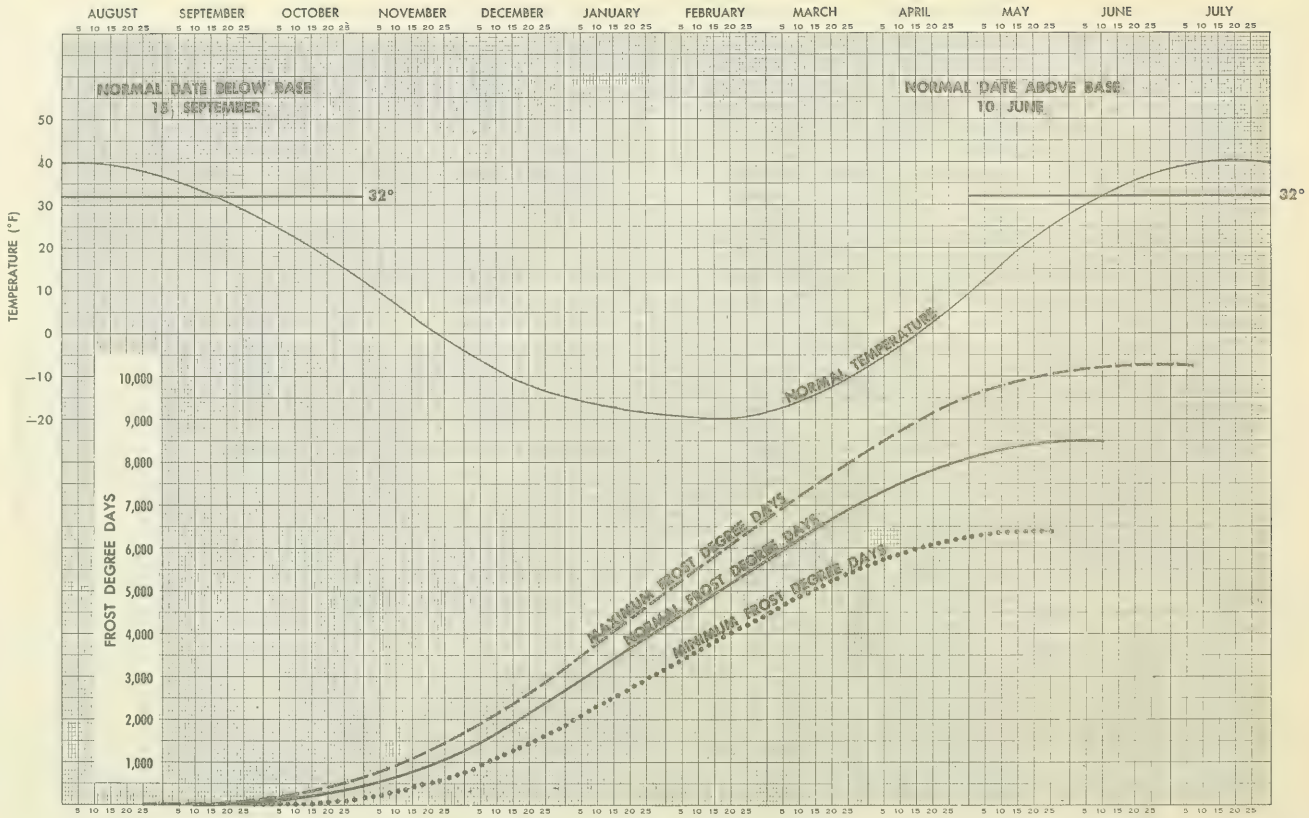

FIGURE 24A CLYDE RIVER (11 YEARS RECORD)

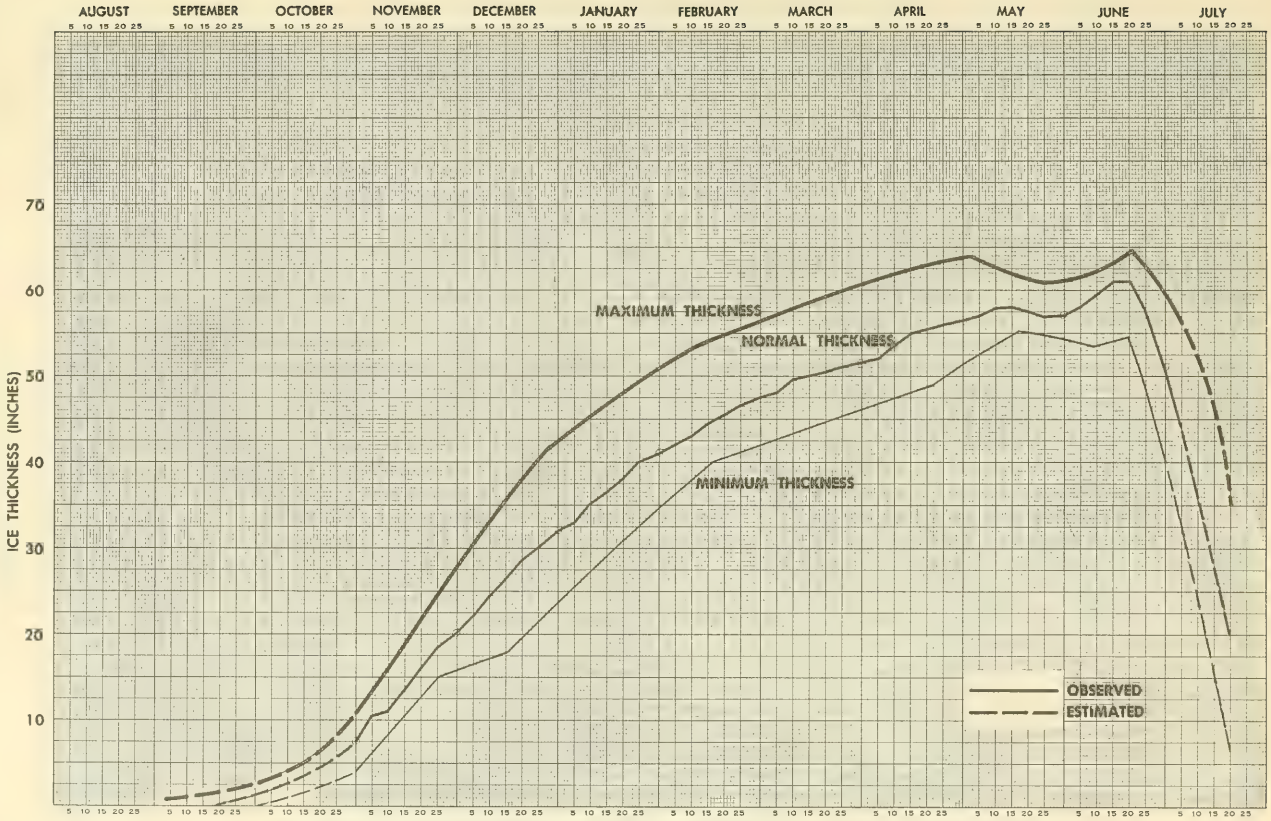

FIGURE 24B CLYDE RIVER EMPIRICAL ICE GROWTH AND DISINTEGRATION CURVE (3 YEARS RECORD)

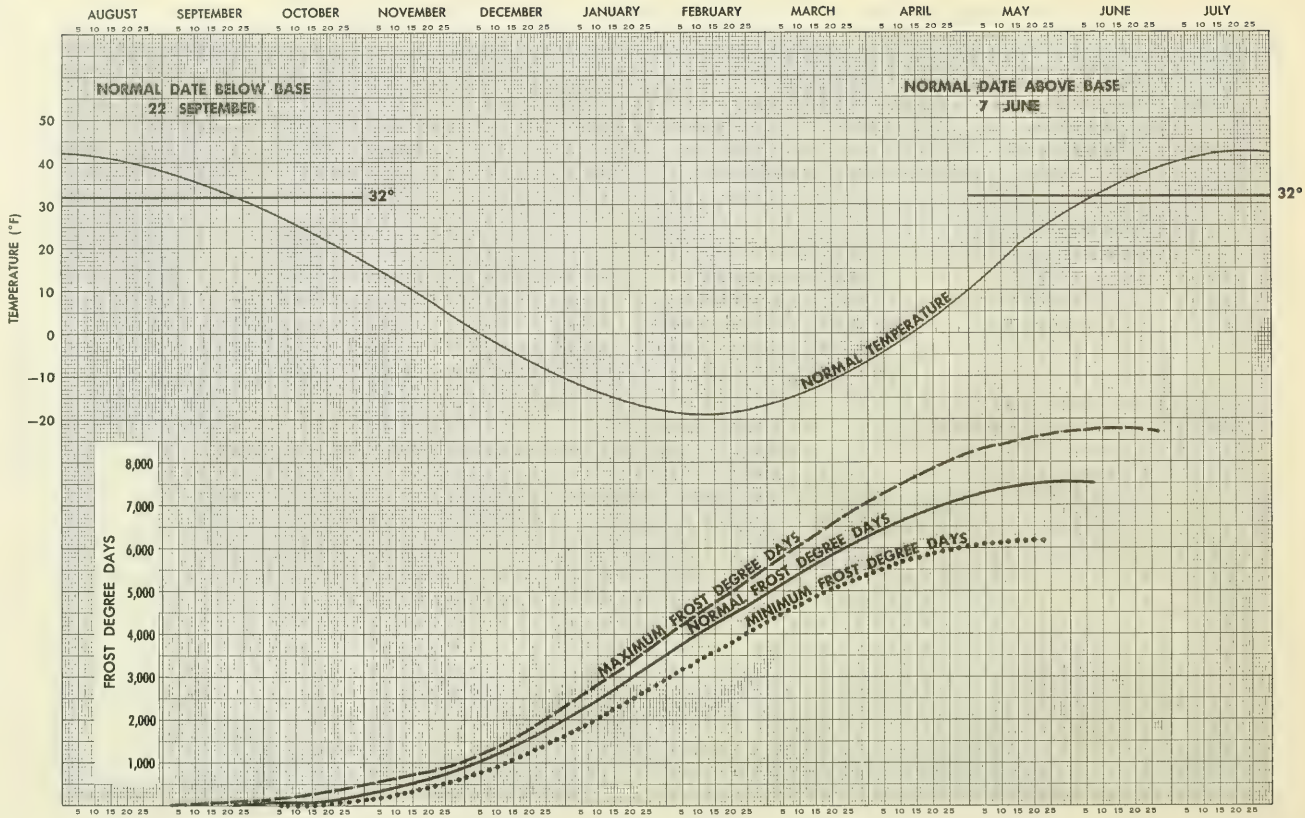

FIGURE 25A PADLOPING ISLAND (10 YEARS RECORD)

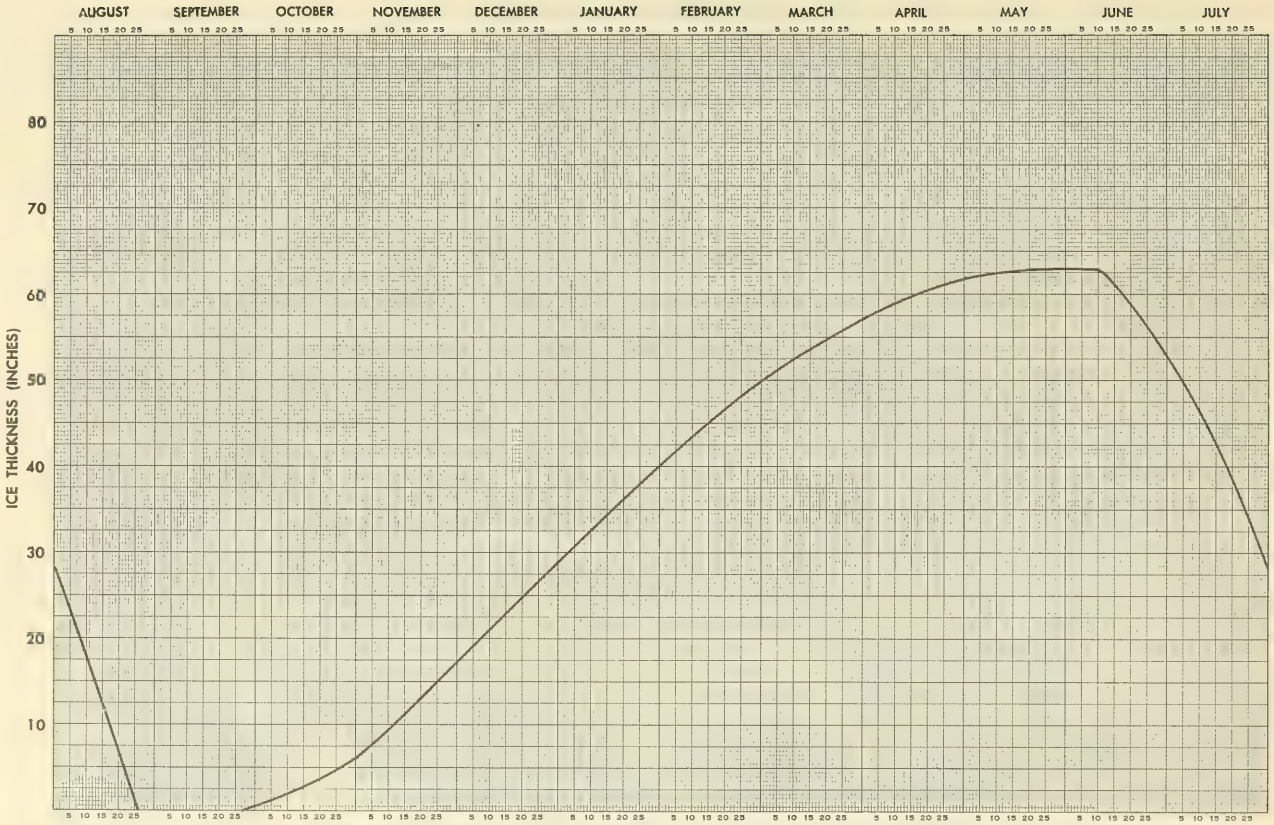

FIGURE 25B PADLOPING ISLAND THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

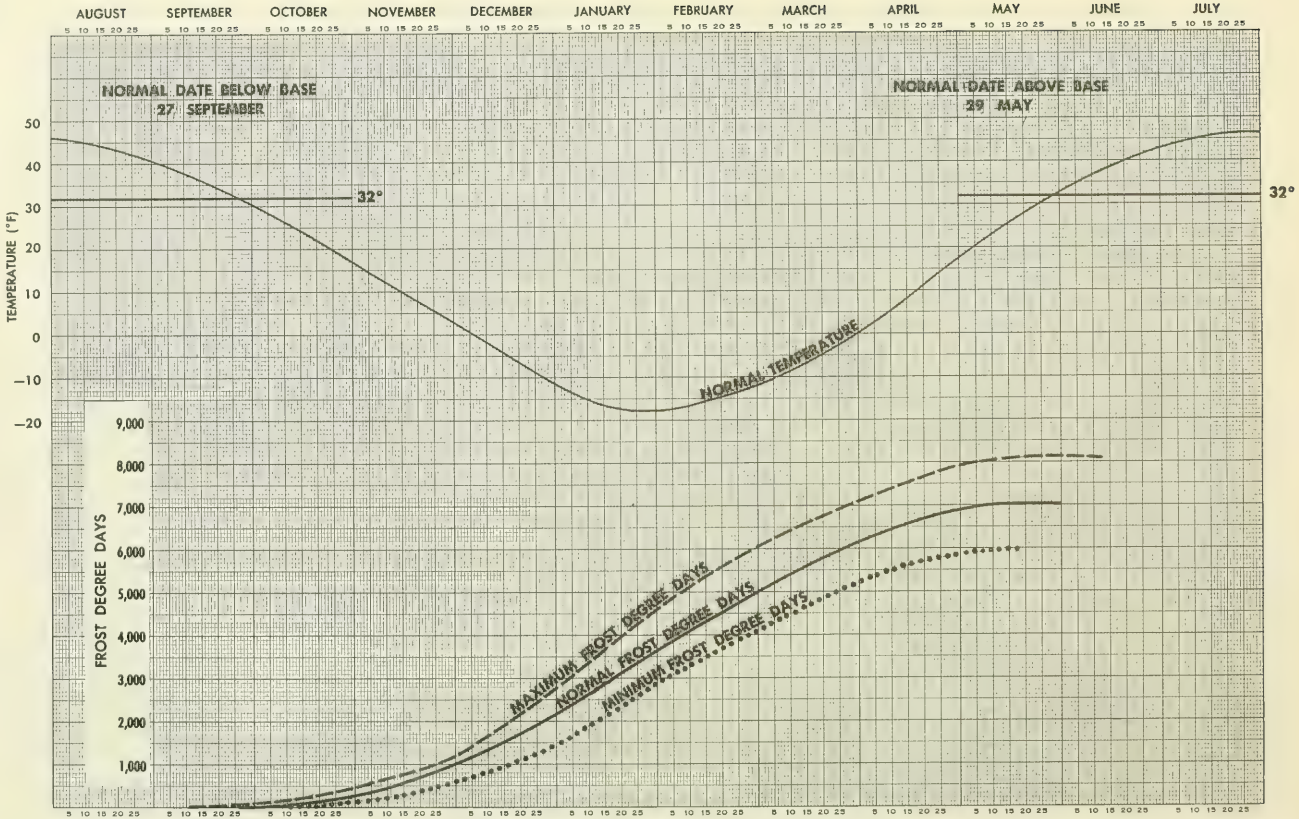

FIGURE 26A FROBISHER BAY (10 YEARS RECORD)

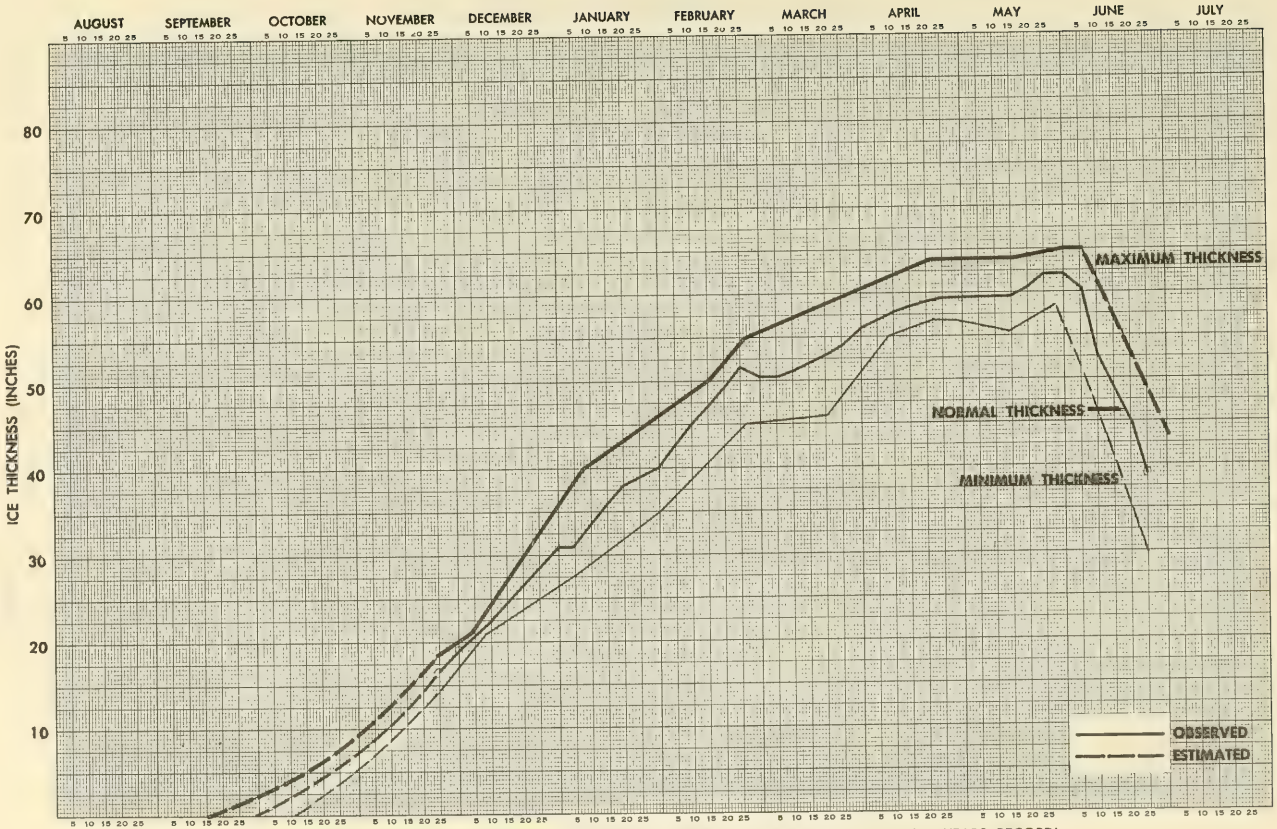

FIGURE 26B FROBISHER BAY EMPIRICAL ICE GROWTH AND DISINTEGRATION CURVE (4 YEARS RECORD)

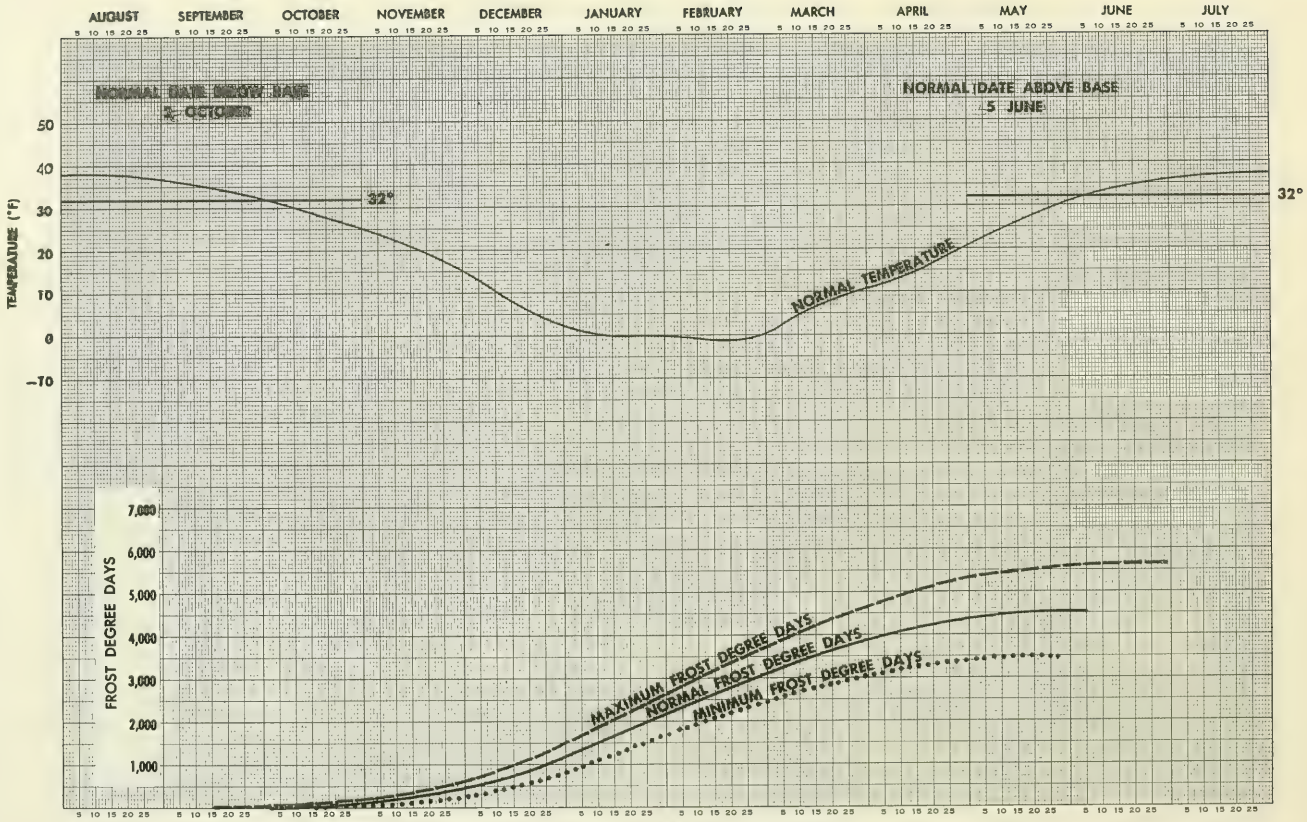

FIGURE 27A RESOLUTION ISLAND (20 YEARS RECORD)

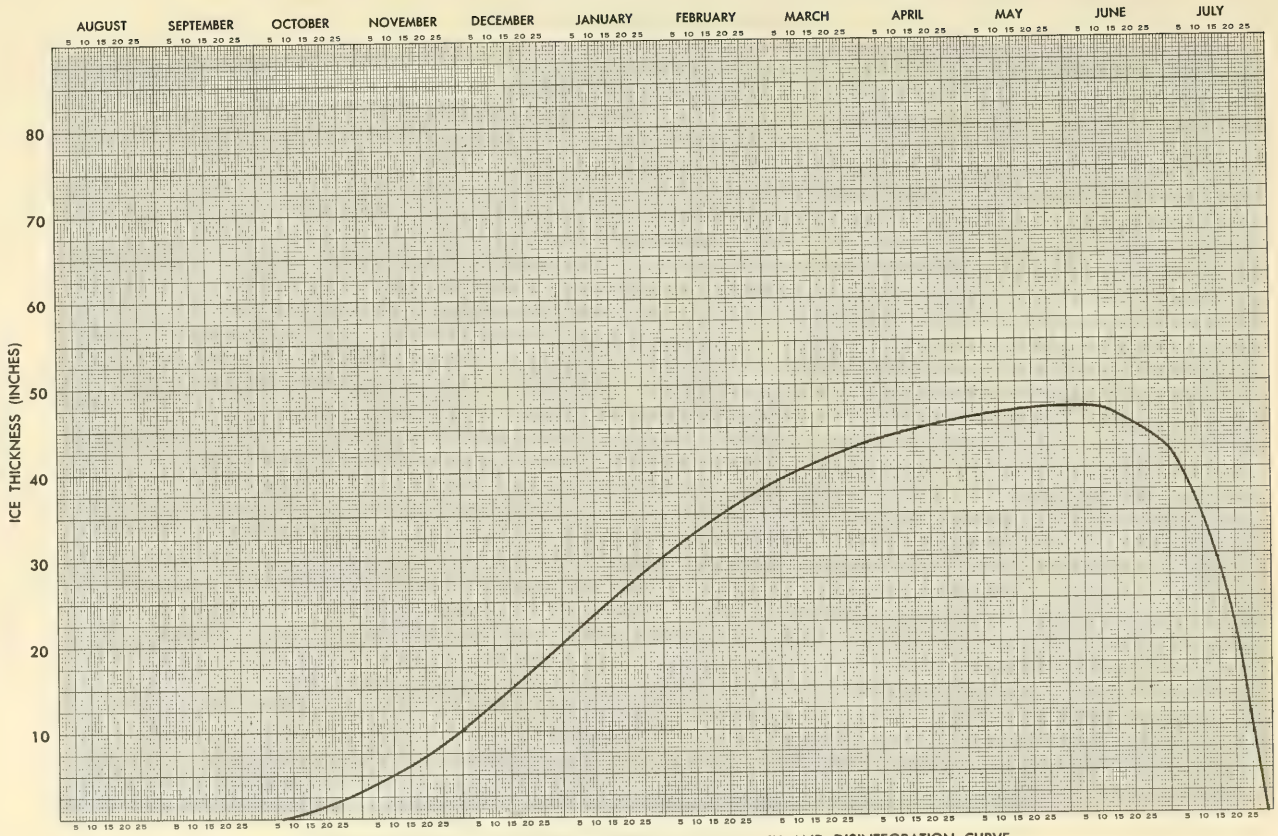

FIGURE 27B RESOLUTION ISLAND THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

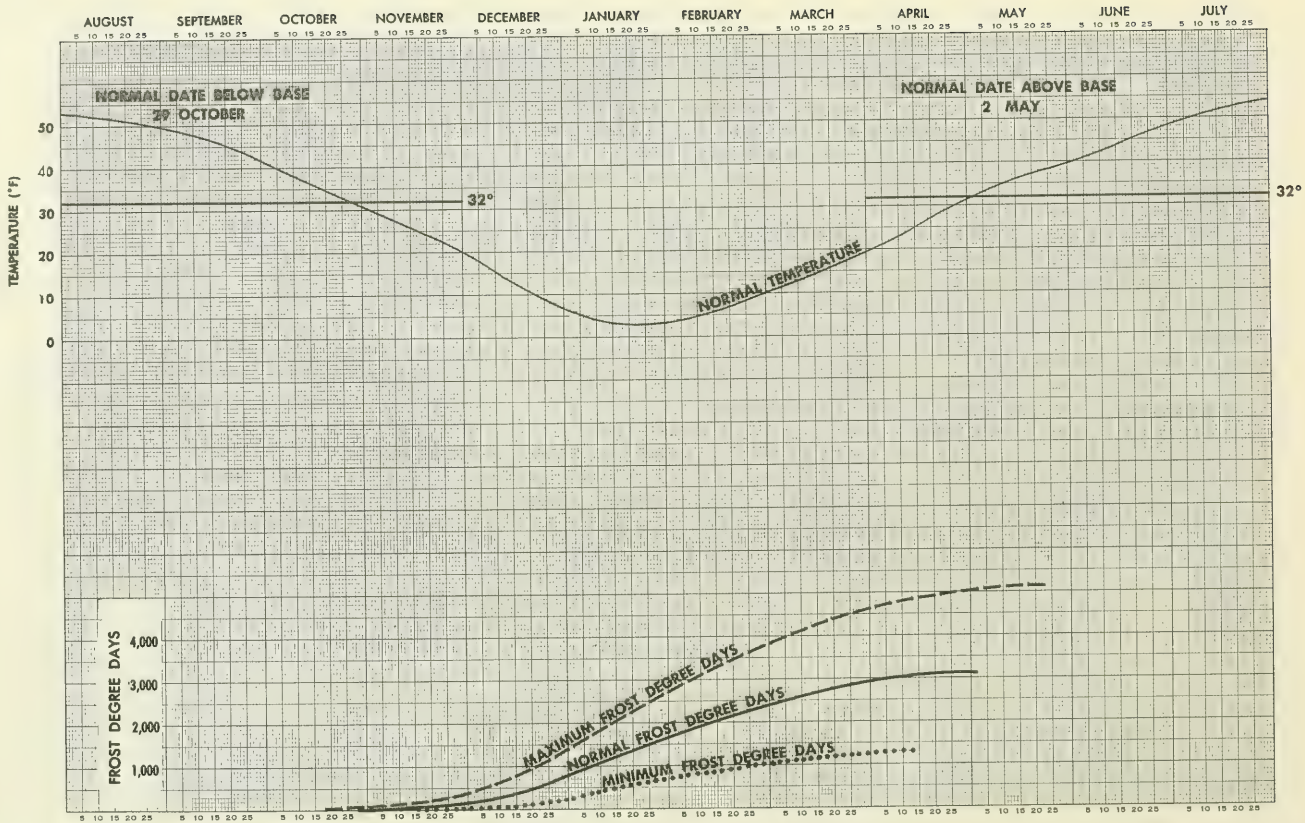

FIGURE 28A HOPEDALE (12 YEARS RECORD)

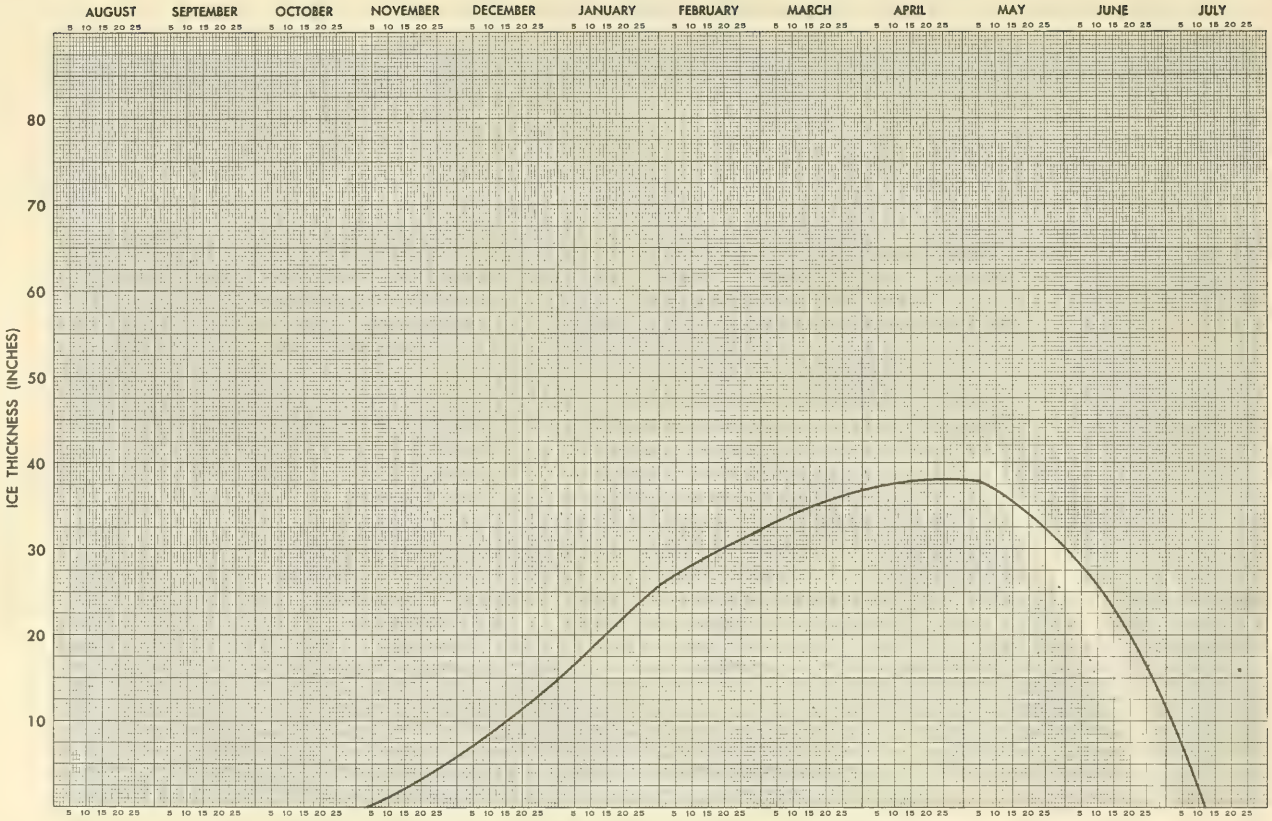

FIGURE 28B HOPEDALE THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

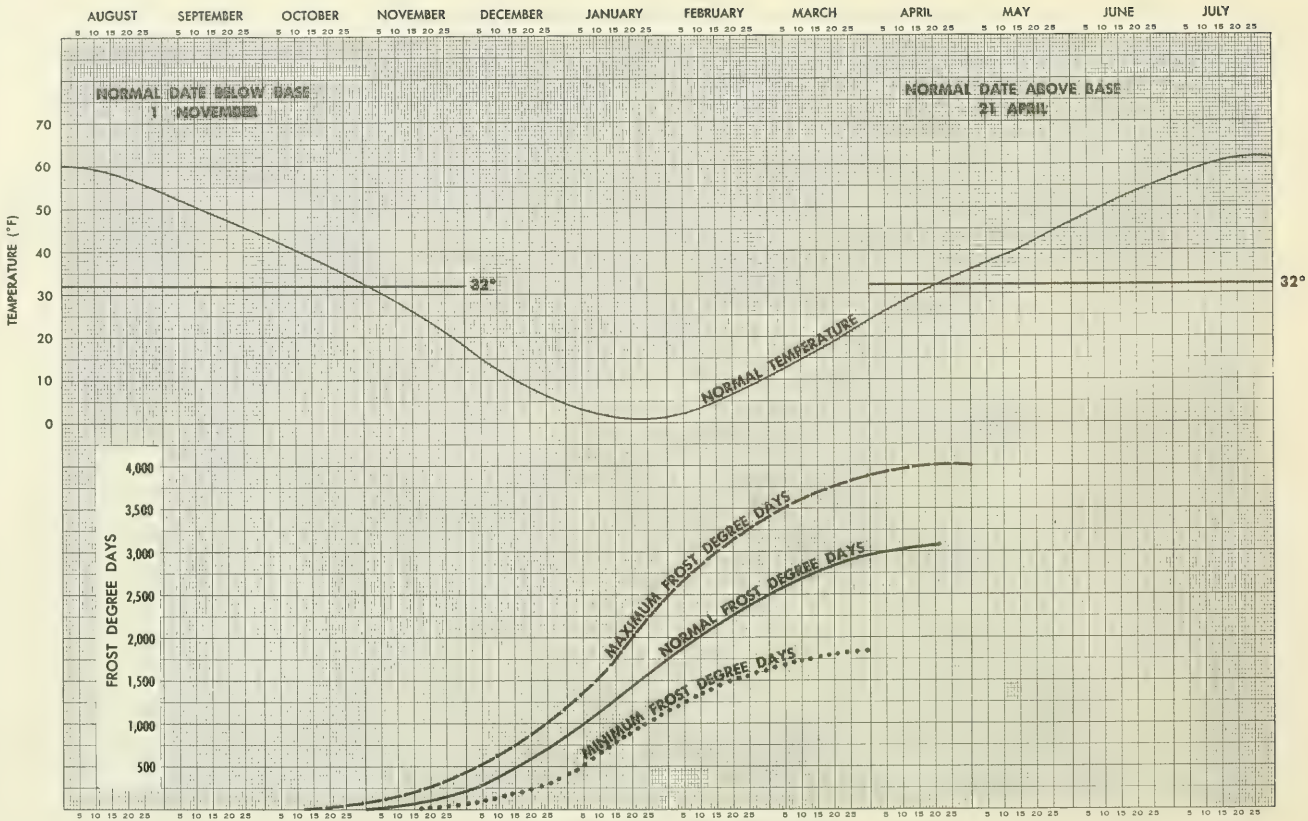

FIGURE 29A GOOSE BAY (10 YEARS RECORD)

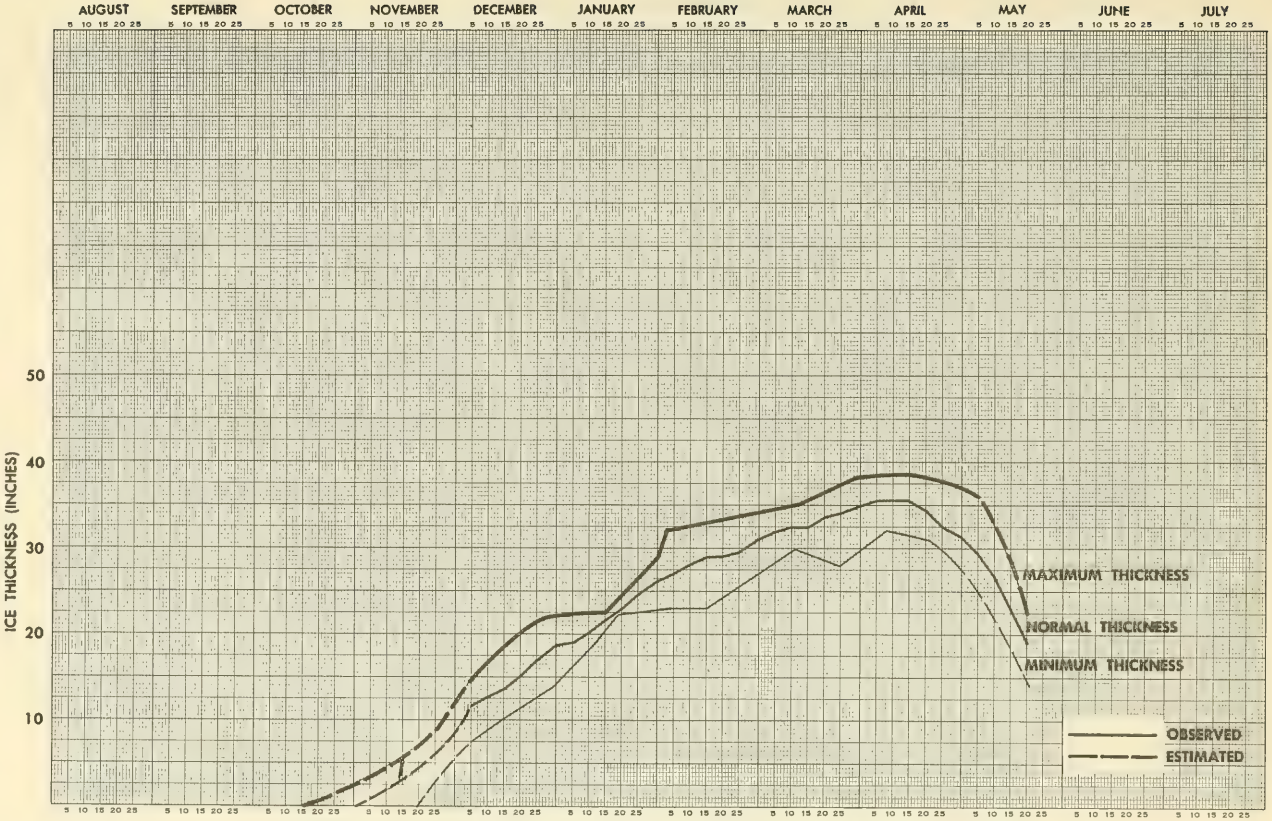

FIGURE 29B GOOSE BAY EMPIRICAL ICE GROWTH AND DISINTEGRATION CURVE (6 YEARS RECORD)

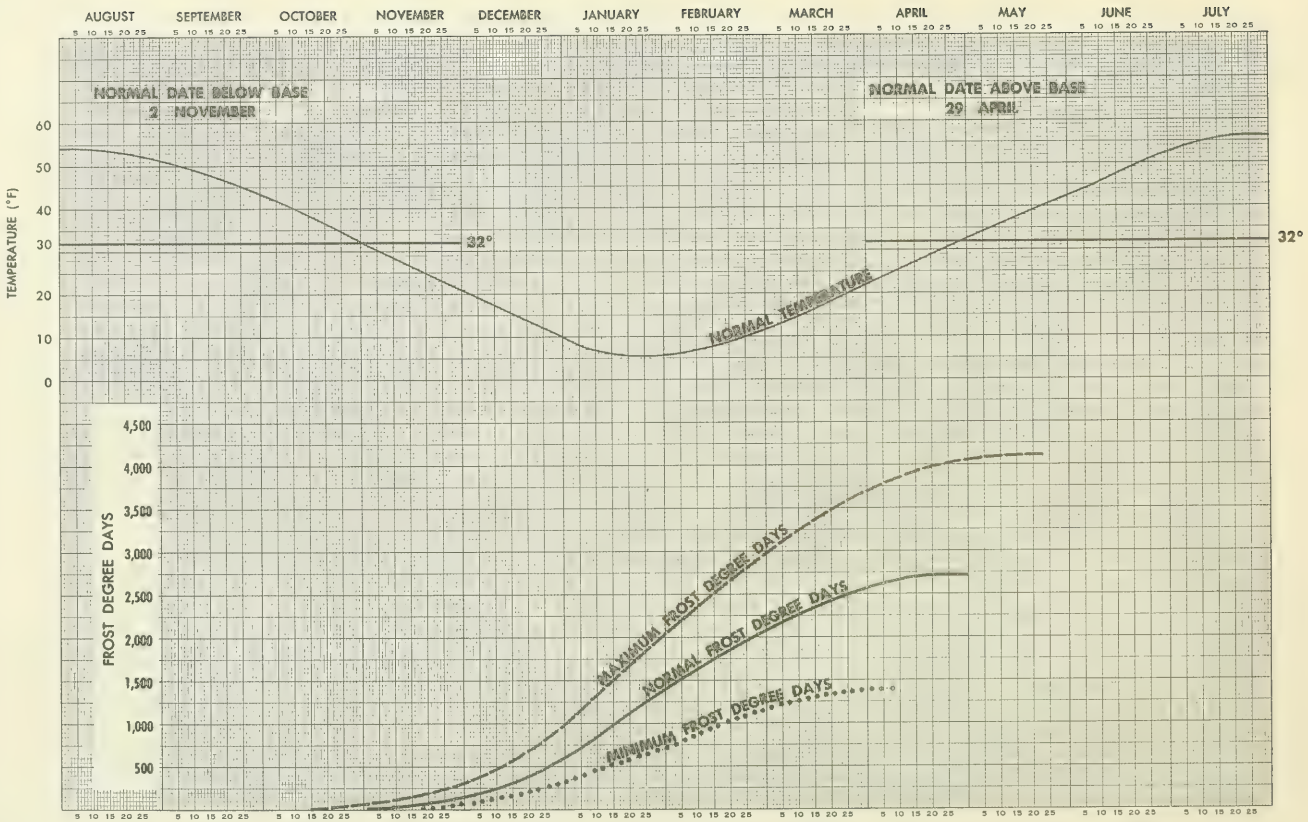

FIGURE 30A CARTWRIGHT (16 YEARS RECORD)

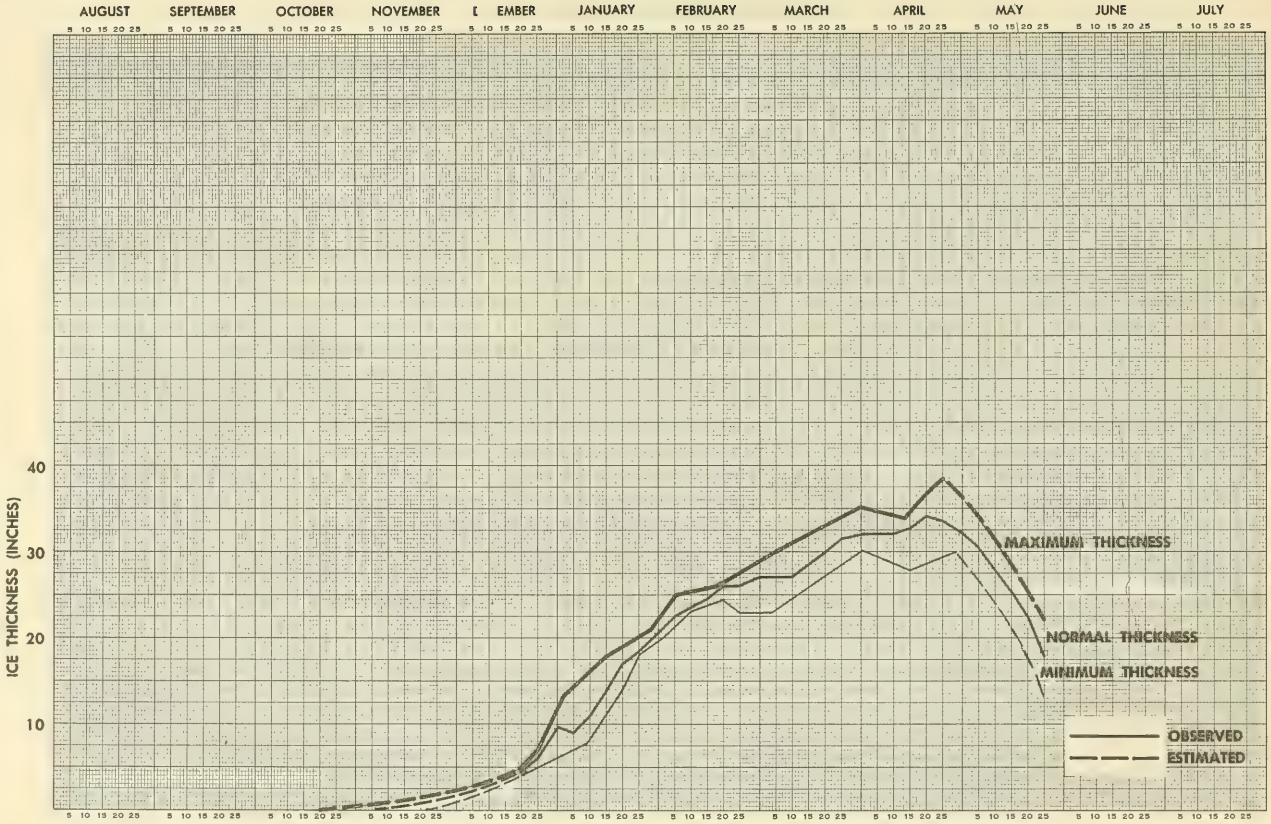

FIGURE 308 CARTWRIGHT EMPIRICAL ICE GROWTH AND DISINTEGRATION CURVE (3 YEARS RECORD)

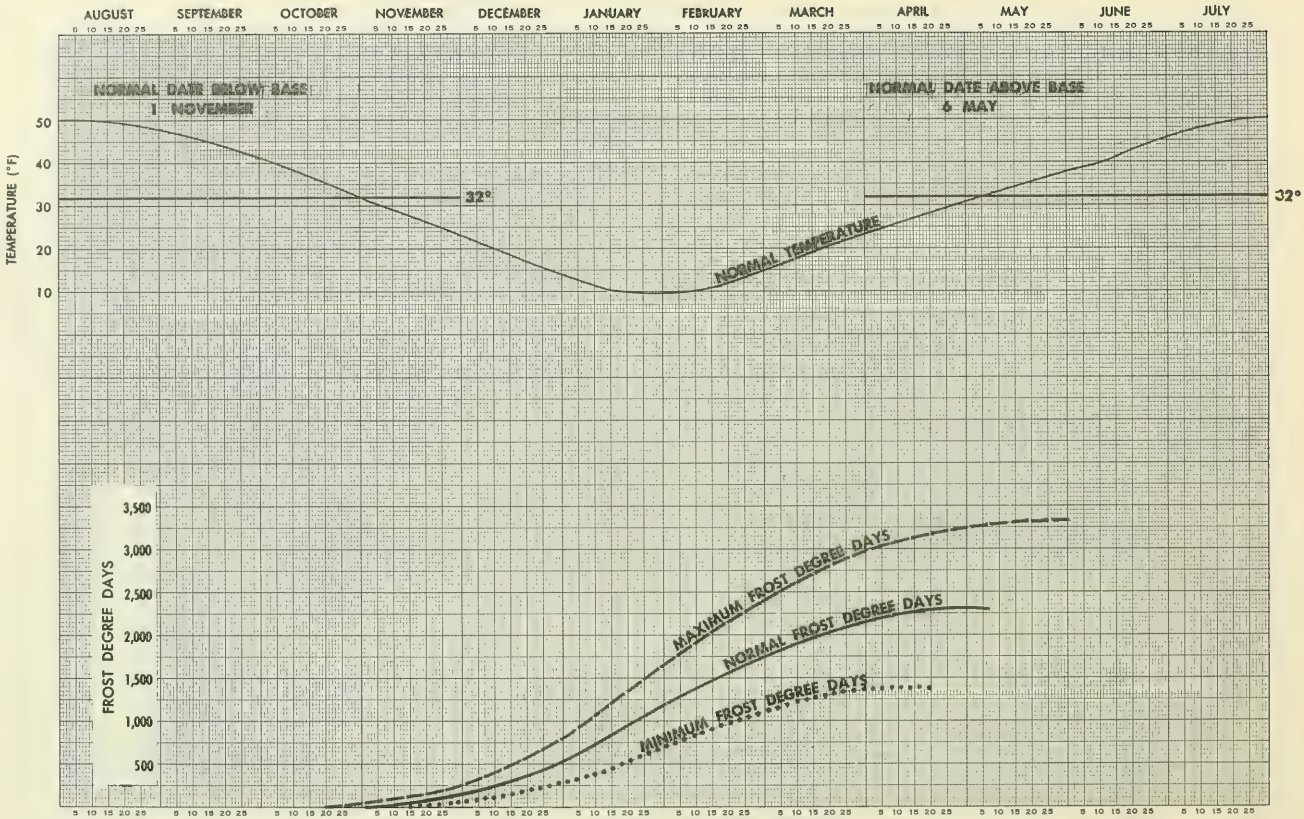

FIGURE 31A BELLE ISLE (27 YEARS RECORD)

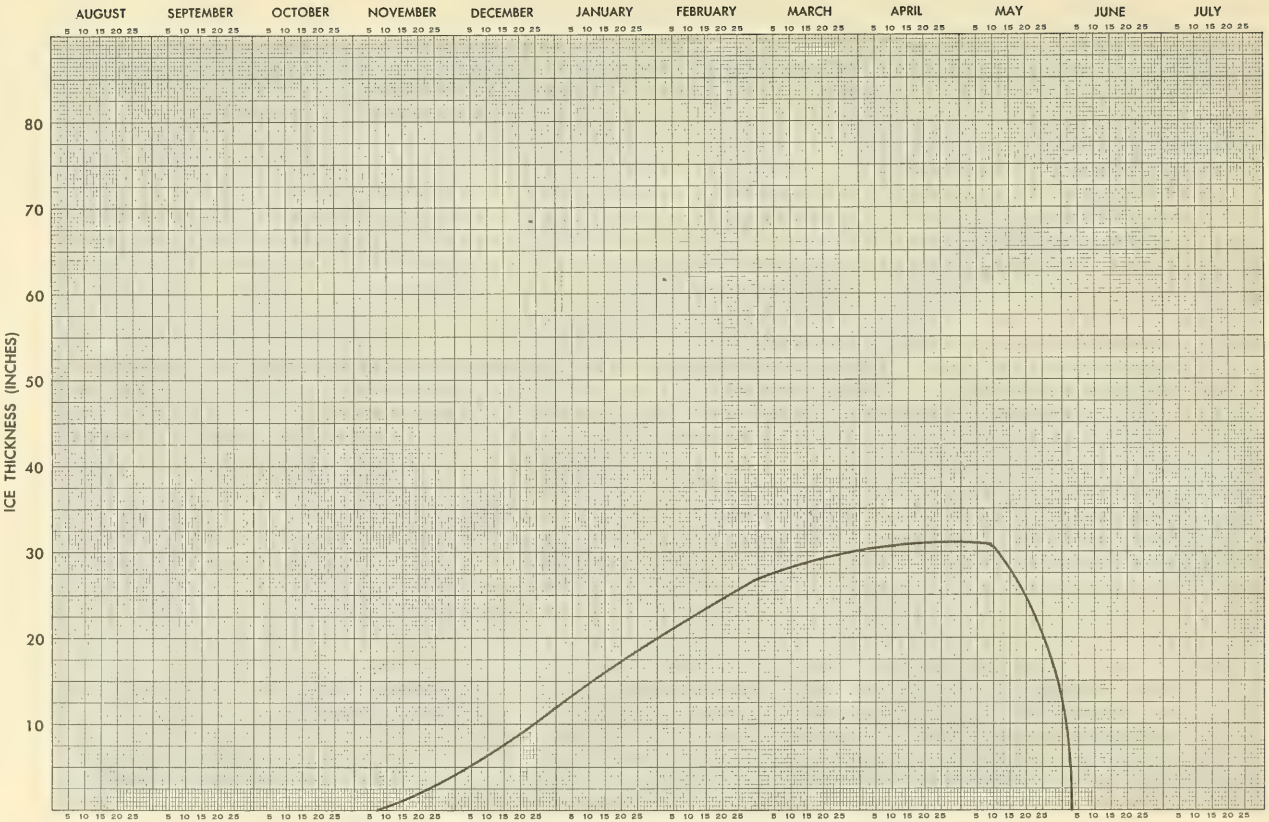

FIGURE 31B BELLE ISLE THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

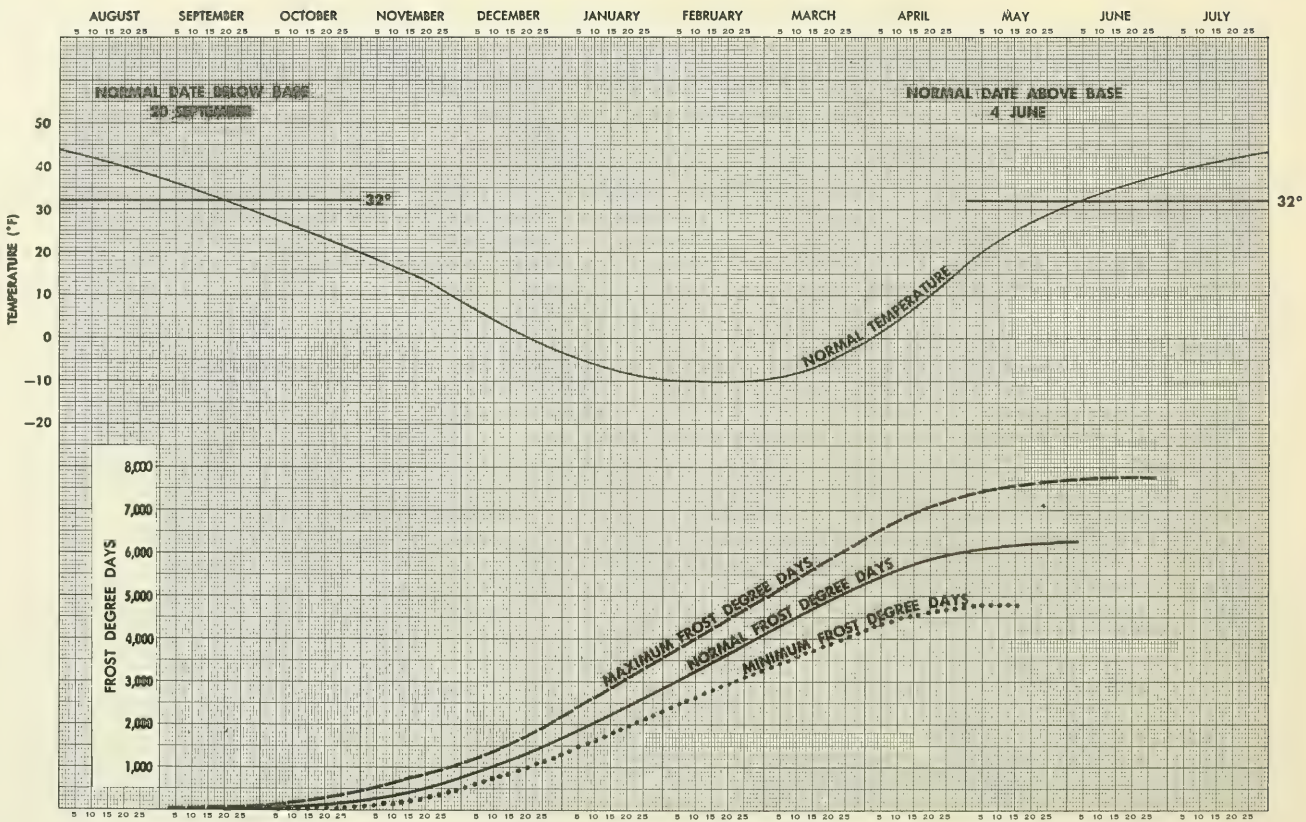

FIGURE 32A UPERNAVIK (50 YEARS RECORD)

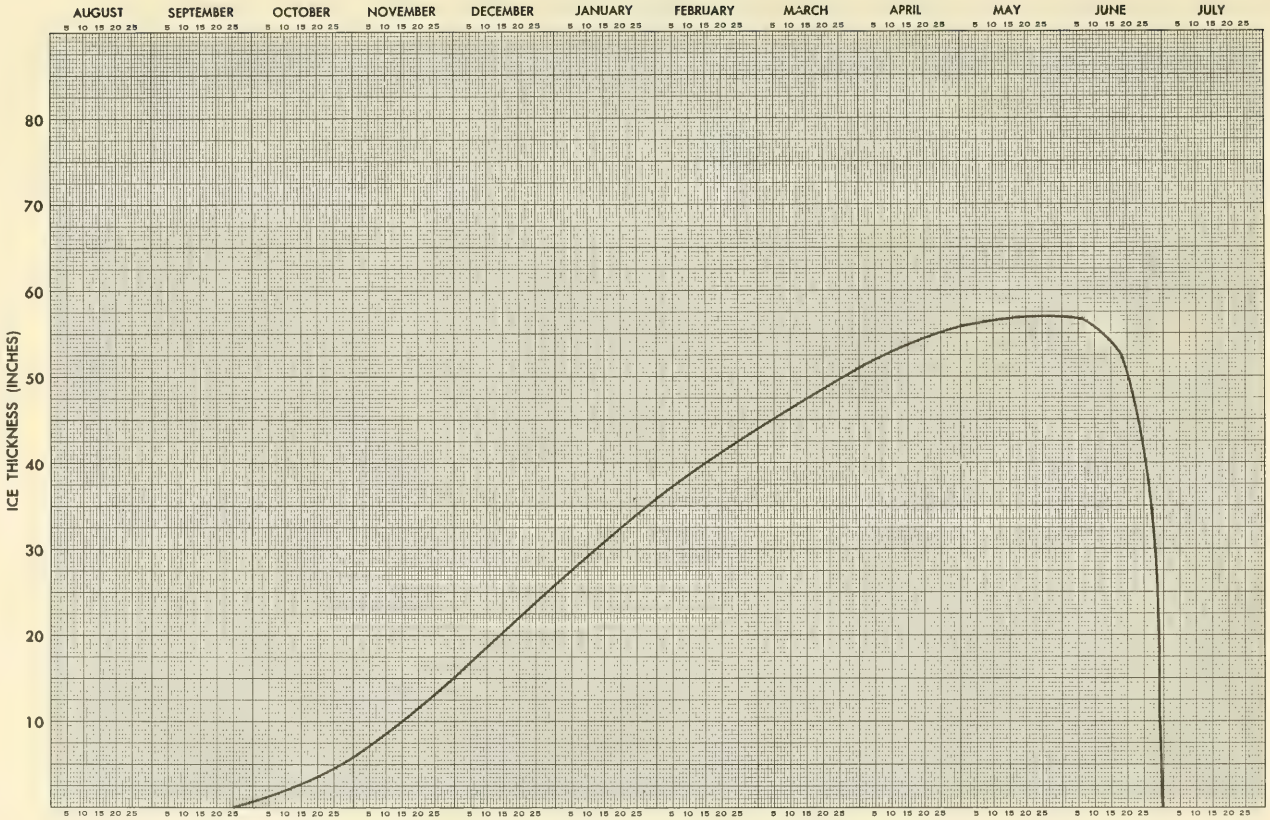

FIGURE 32B UPERNAVIK THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

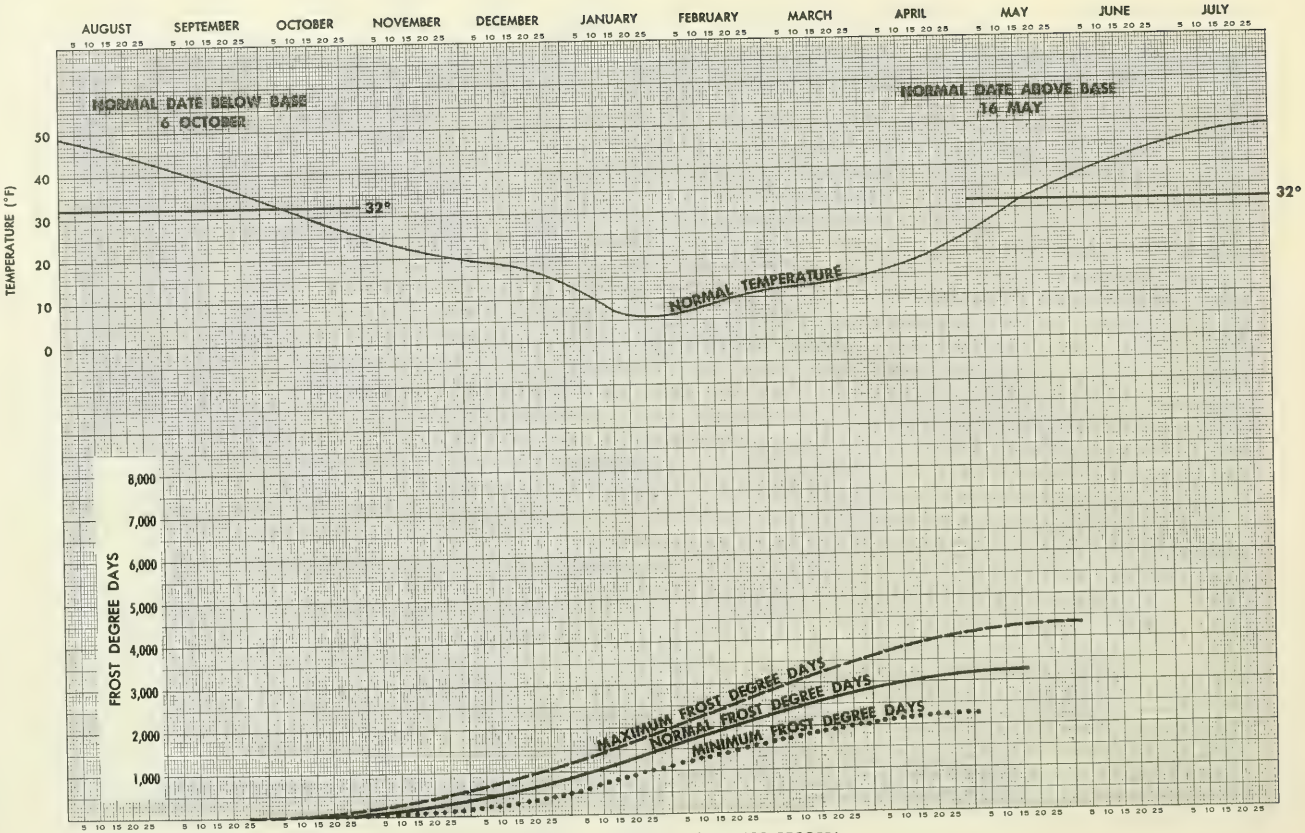

FIGURE 33A UMANAK (5 YEARS RECORD)

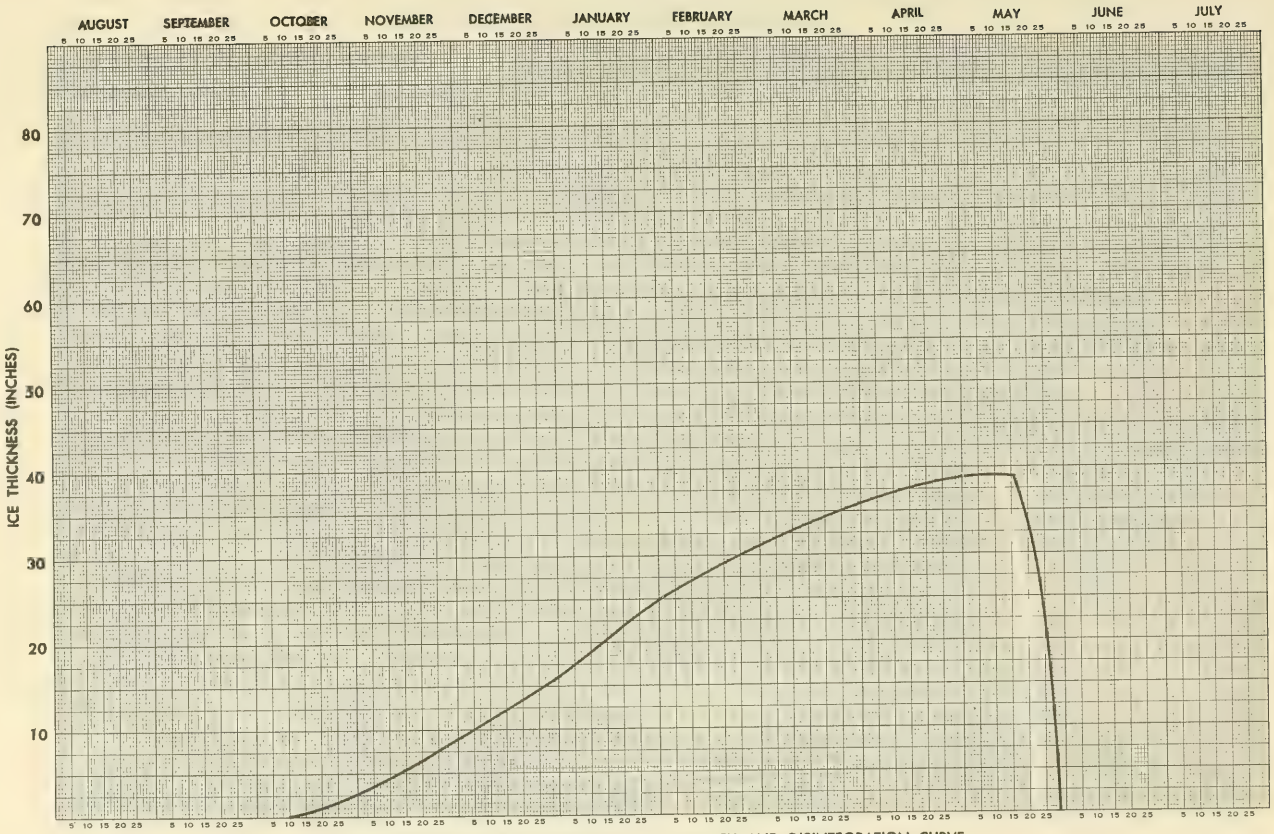

FIGURE 33B UMANAK THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

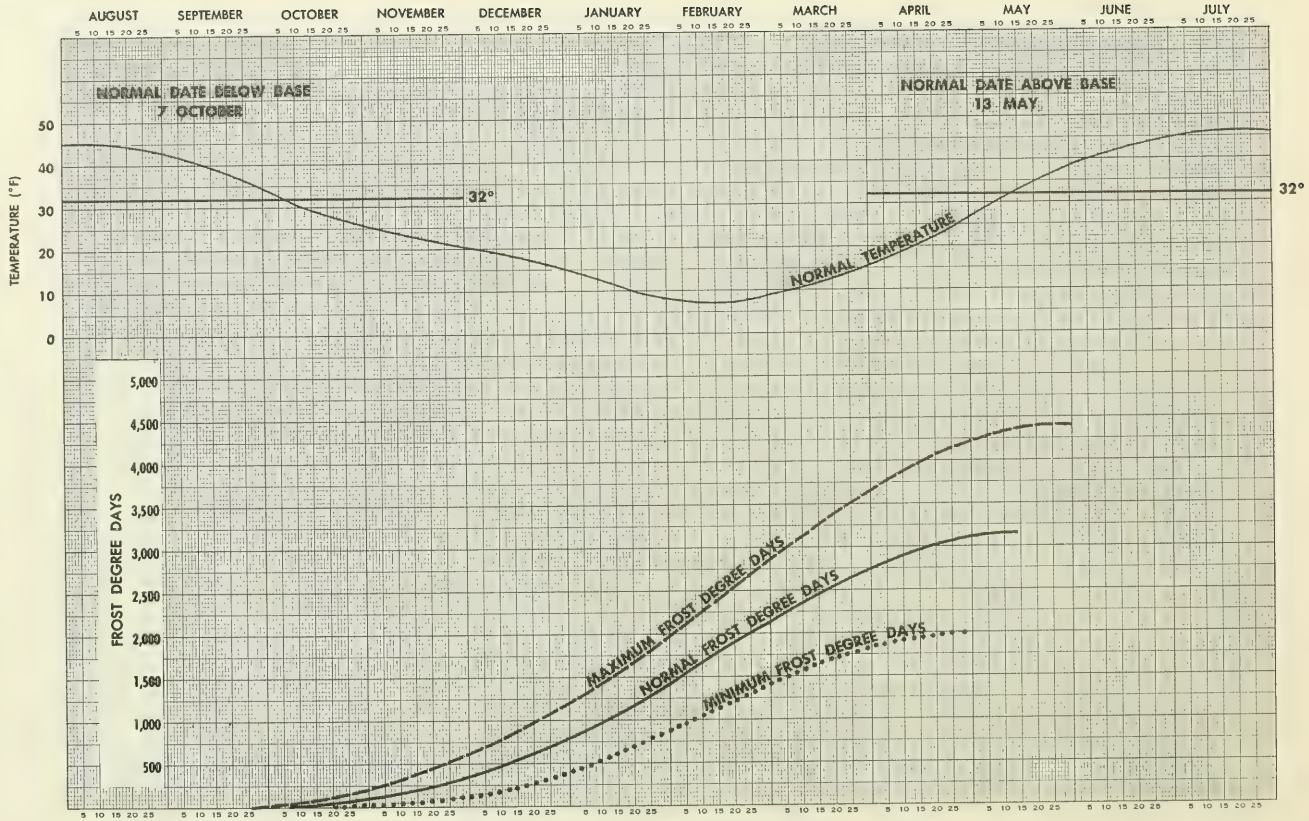

FIGURE 34A GODHAVN (12 YEARS RECORD)

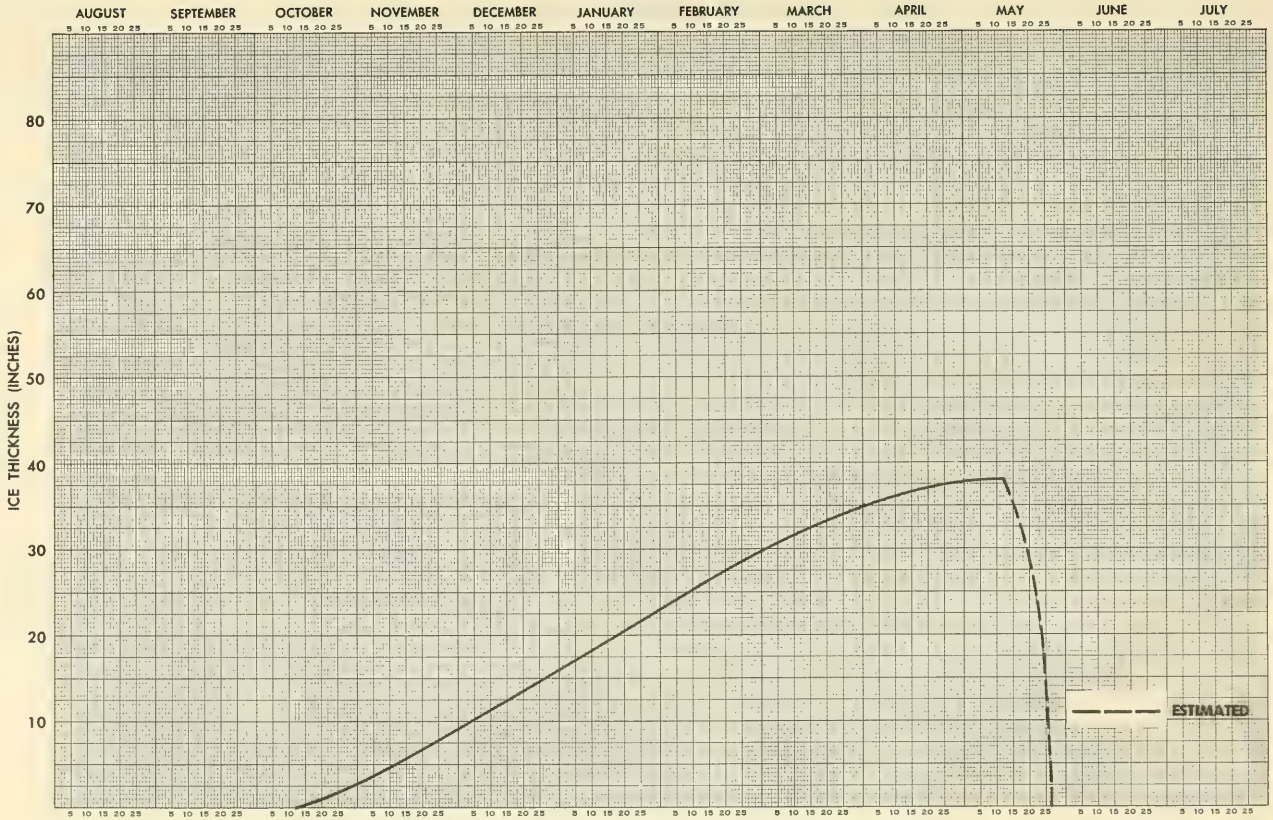

FIGURE 34B GODHAVN THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

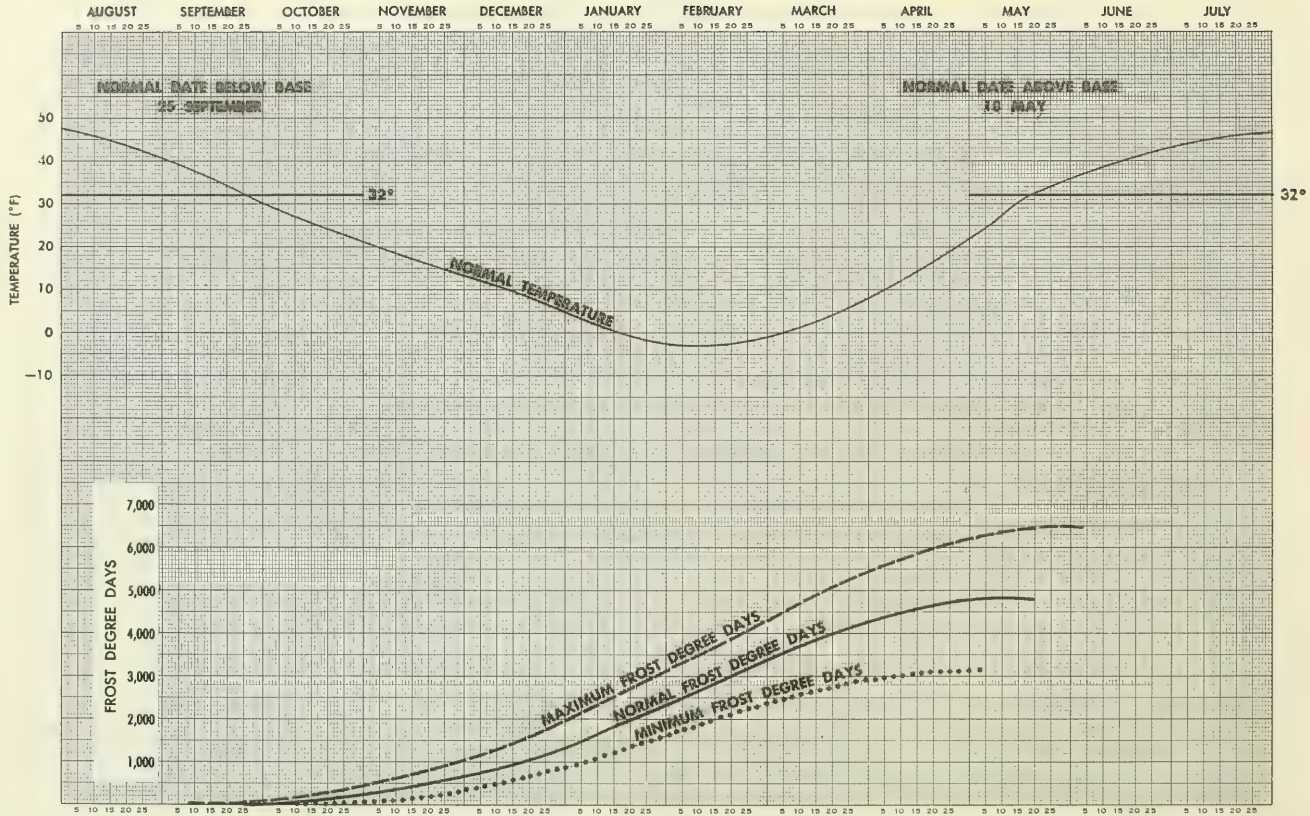

FIGURE 35A JAKOBSHAVN (50 YEARS RECORD)

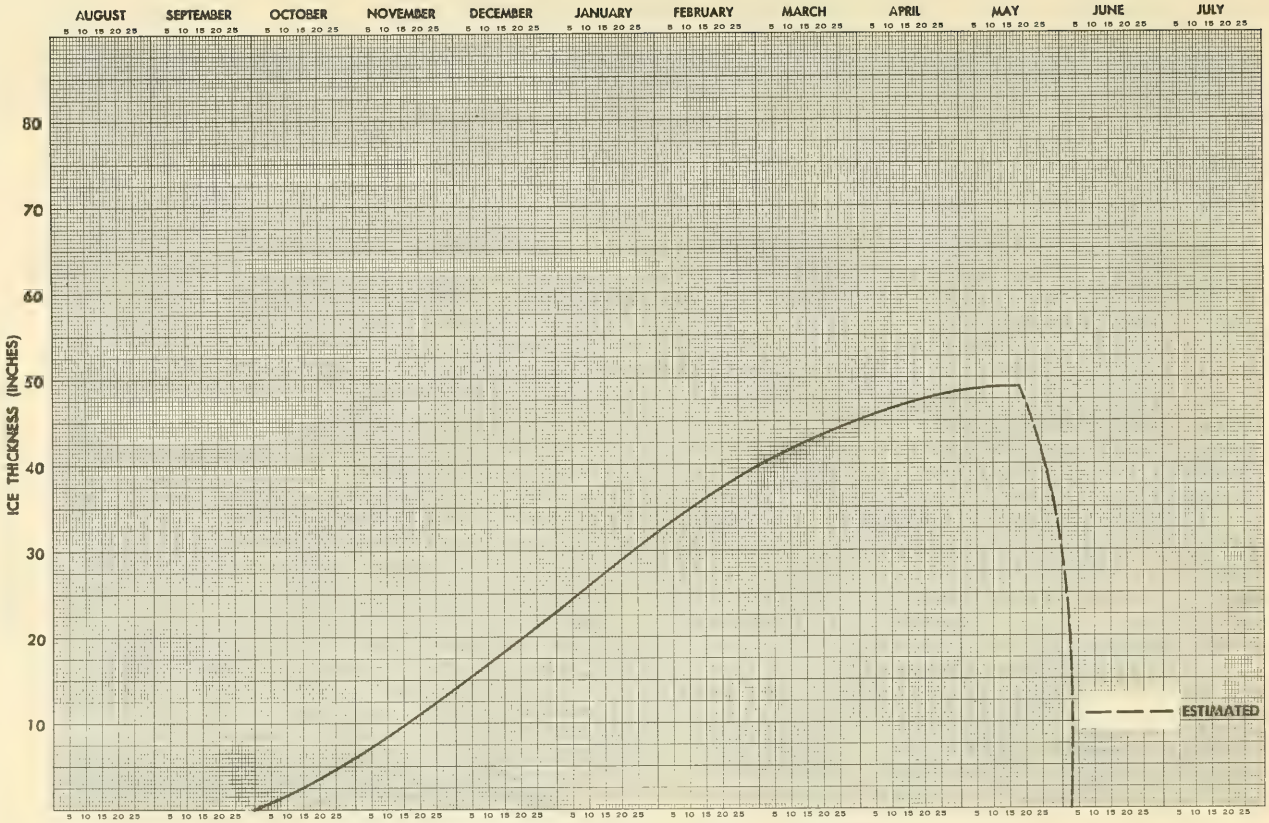

FIGURE 35B JAKOBSHAVN THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

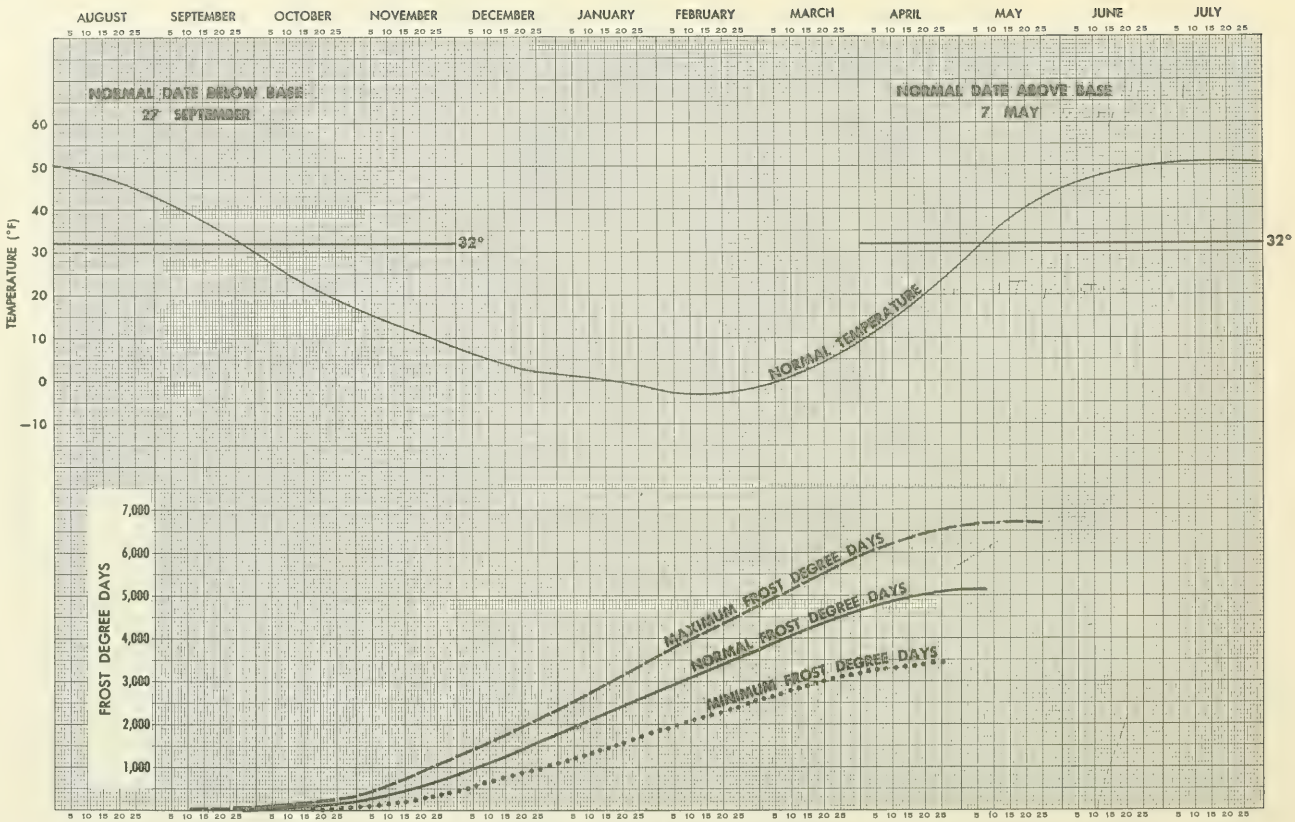

FIGURE 36A SONDRESTROM (12 YEARS RECORD)

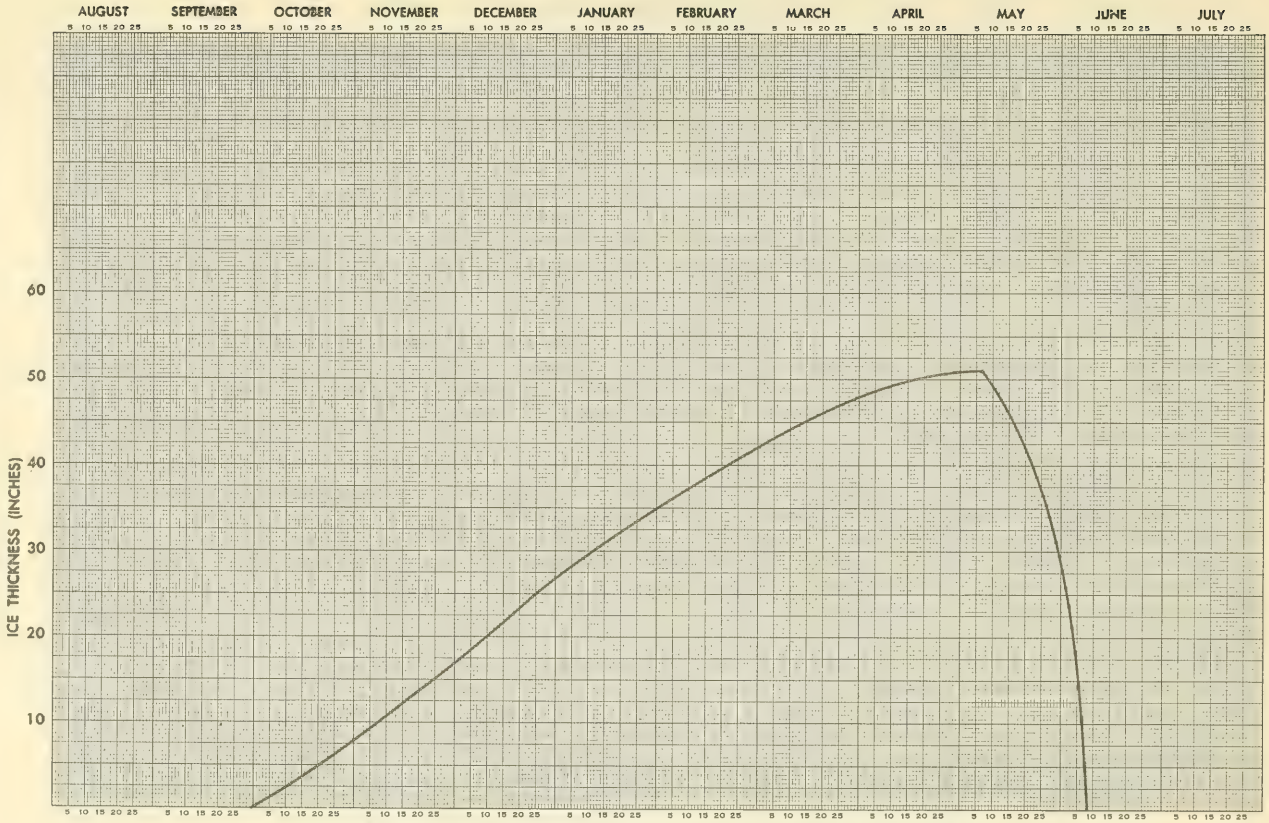

FIGURE 36B SONDRESTROM THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

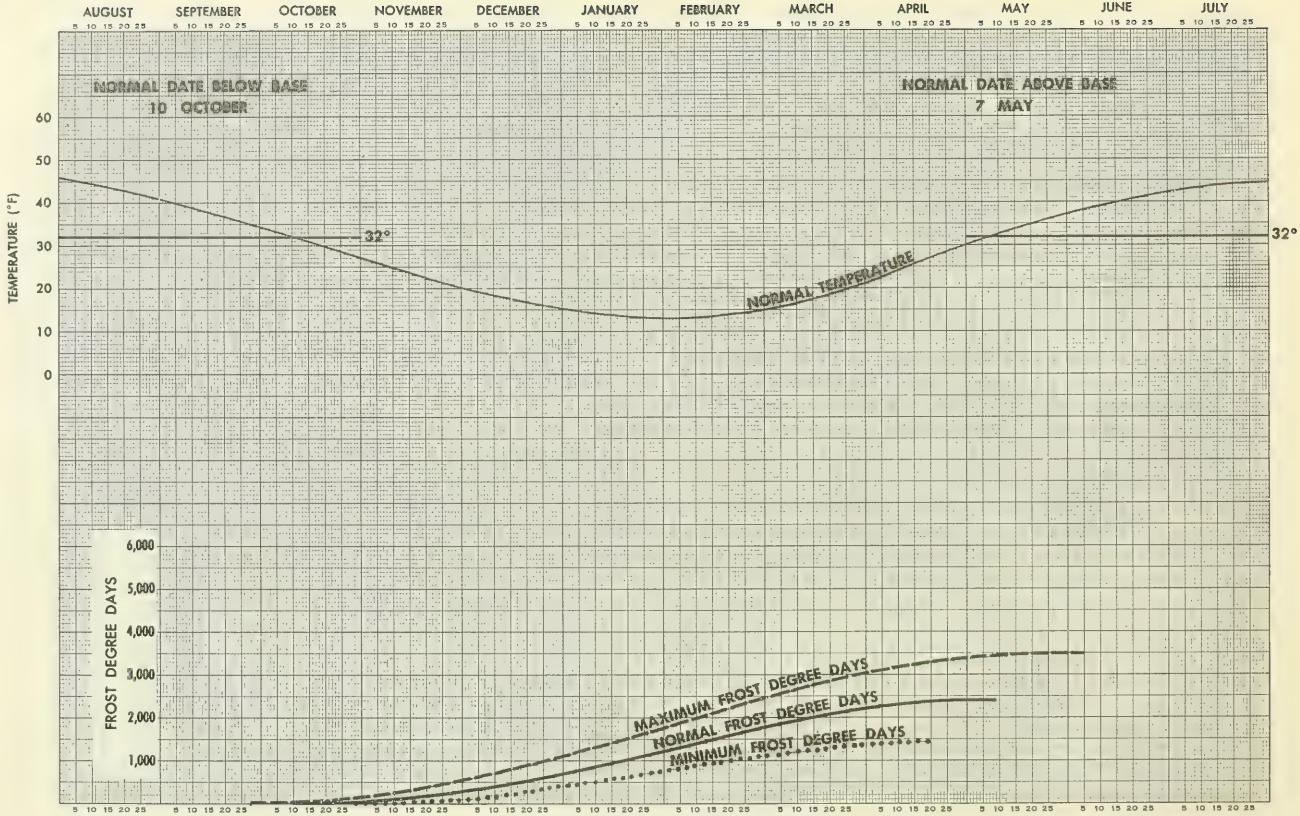

FIGURE 37A GODTHAAB (50 YEARS RECORD)

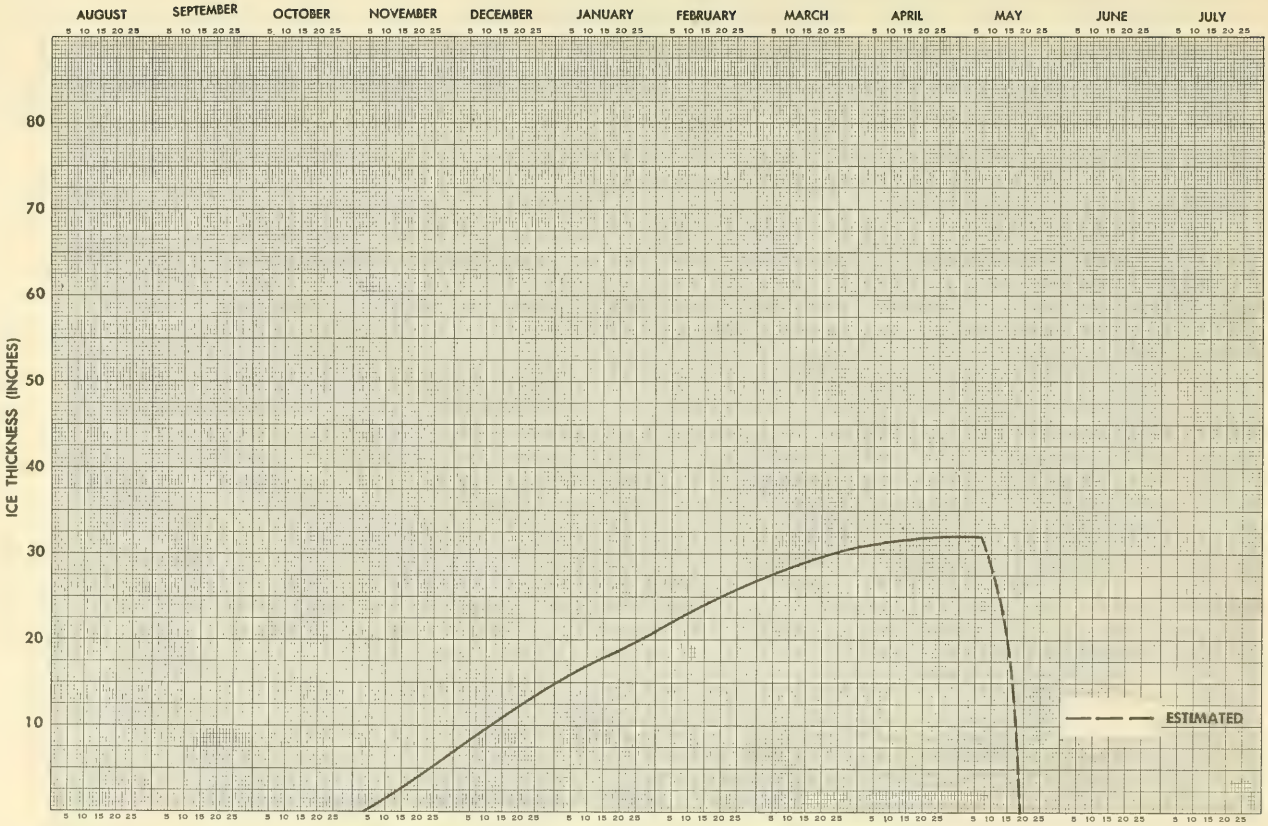

FIGURE 37B GODTHAAB THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

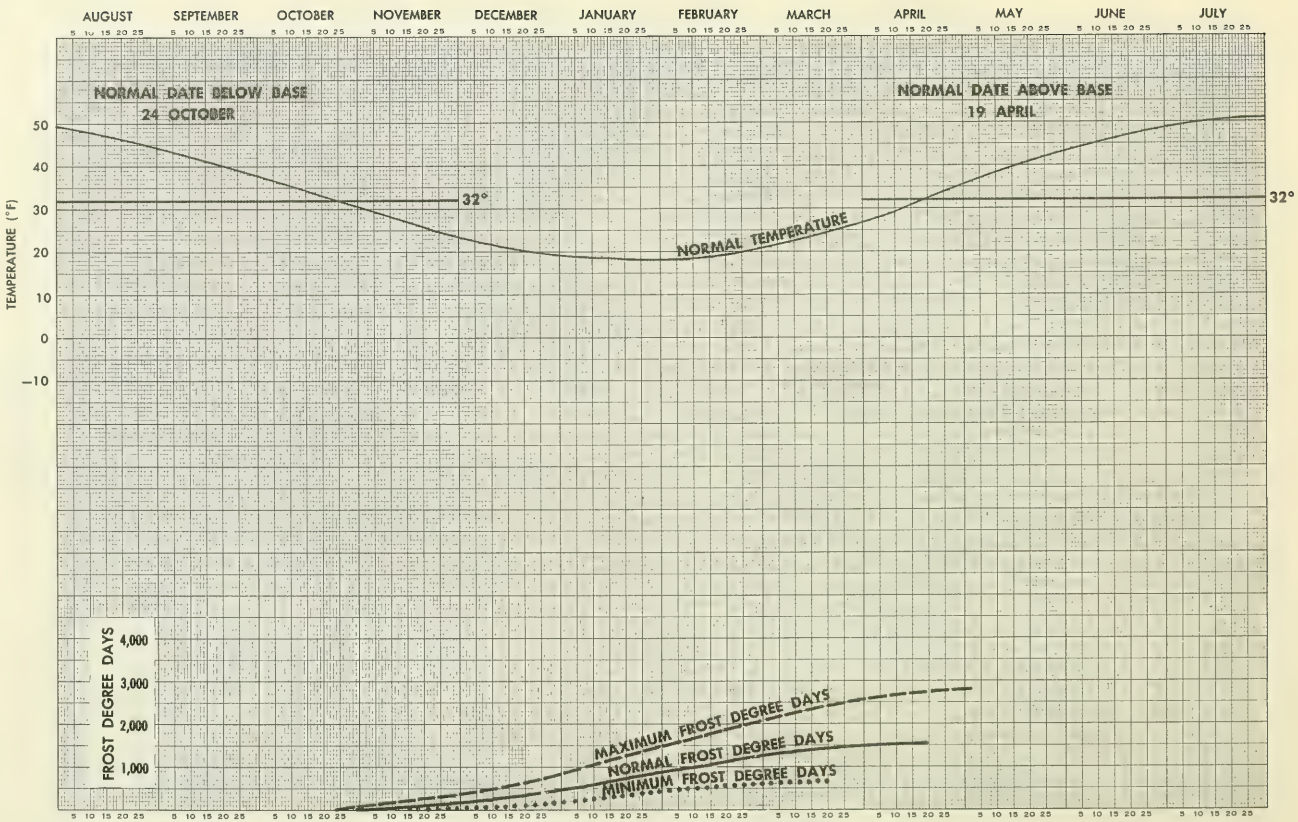

FIGURE 38A IVIGTUT (48 YEARS RECORD)

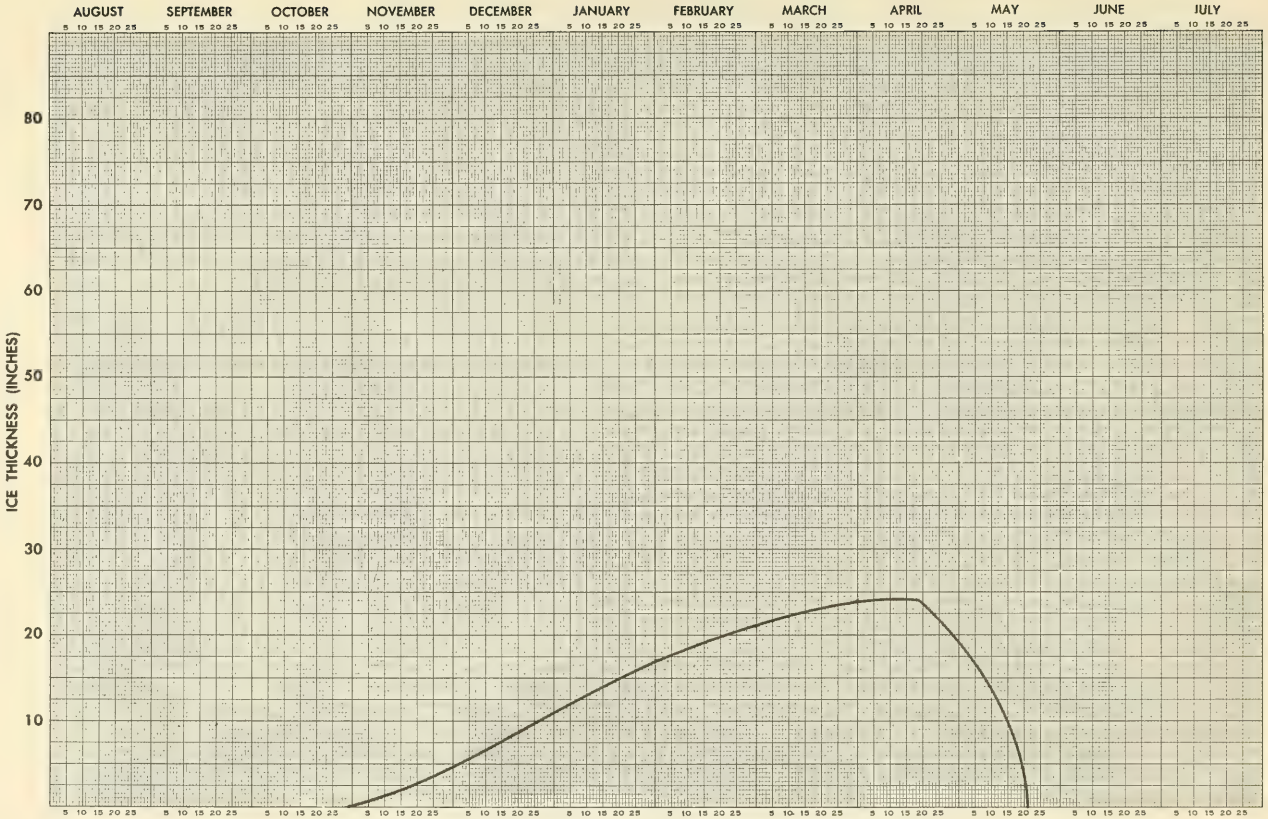

FIGURE 38B IVIGTUT THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

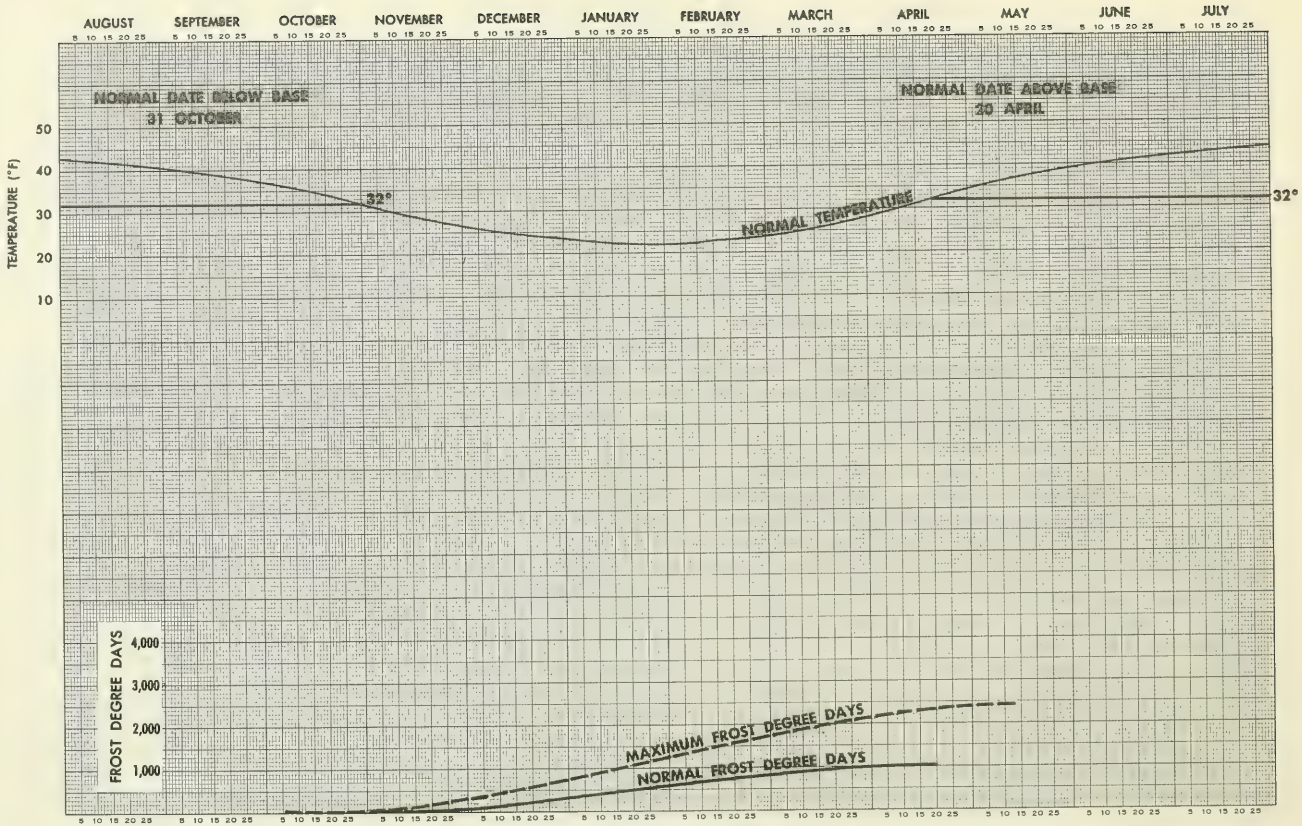

FIGURE 39A NANORTALIK (45 YEARS RECORD)

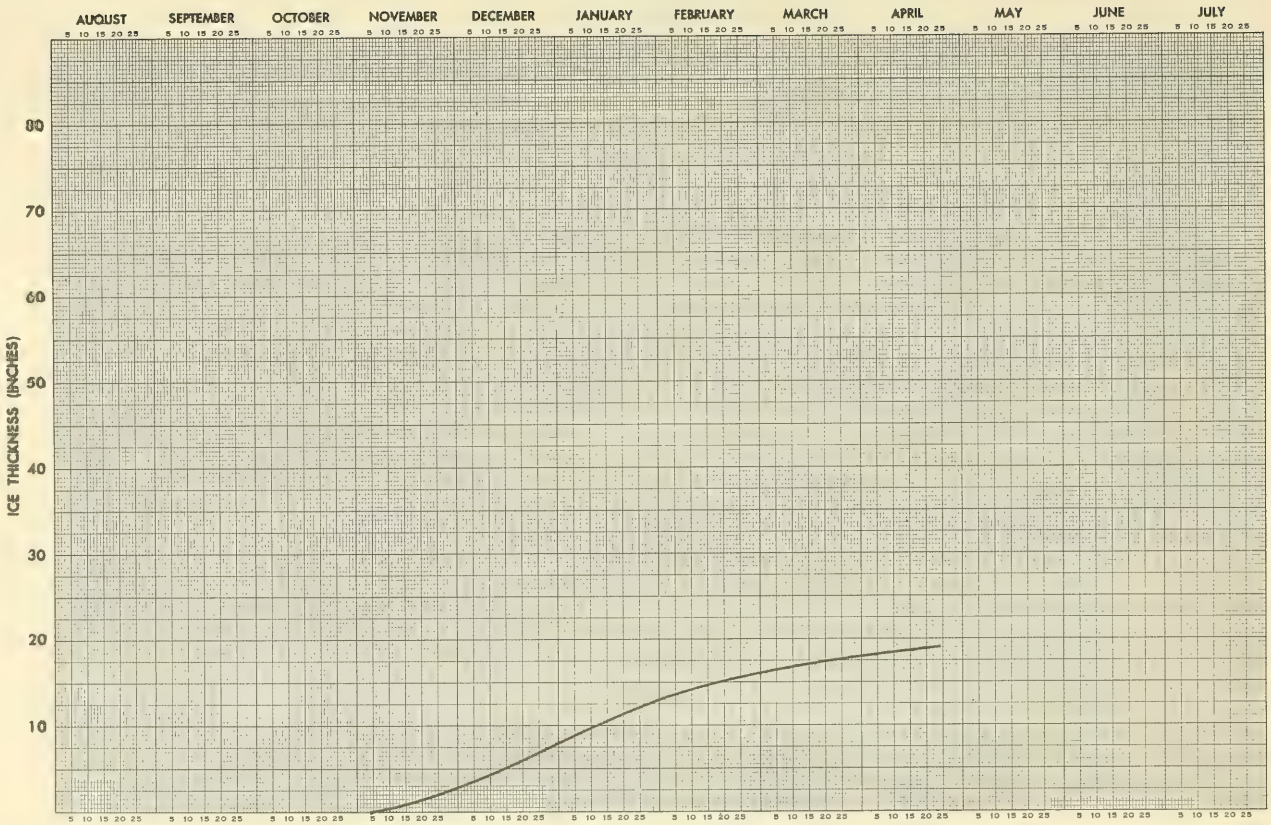

FIGURE 39B NANORTALIK THEORETICAL ICE GROWTH CURVE

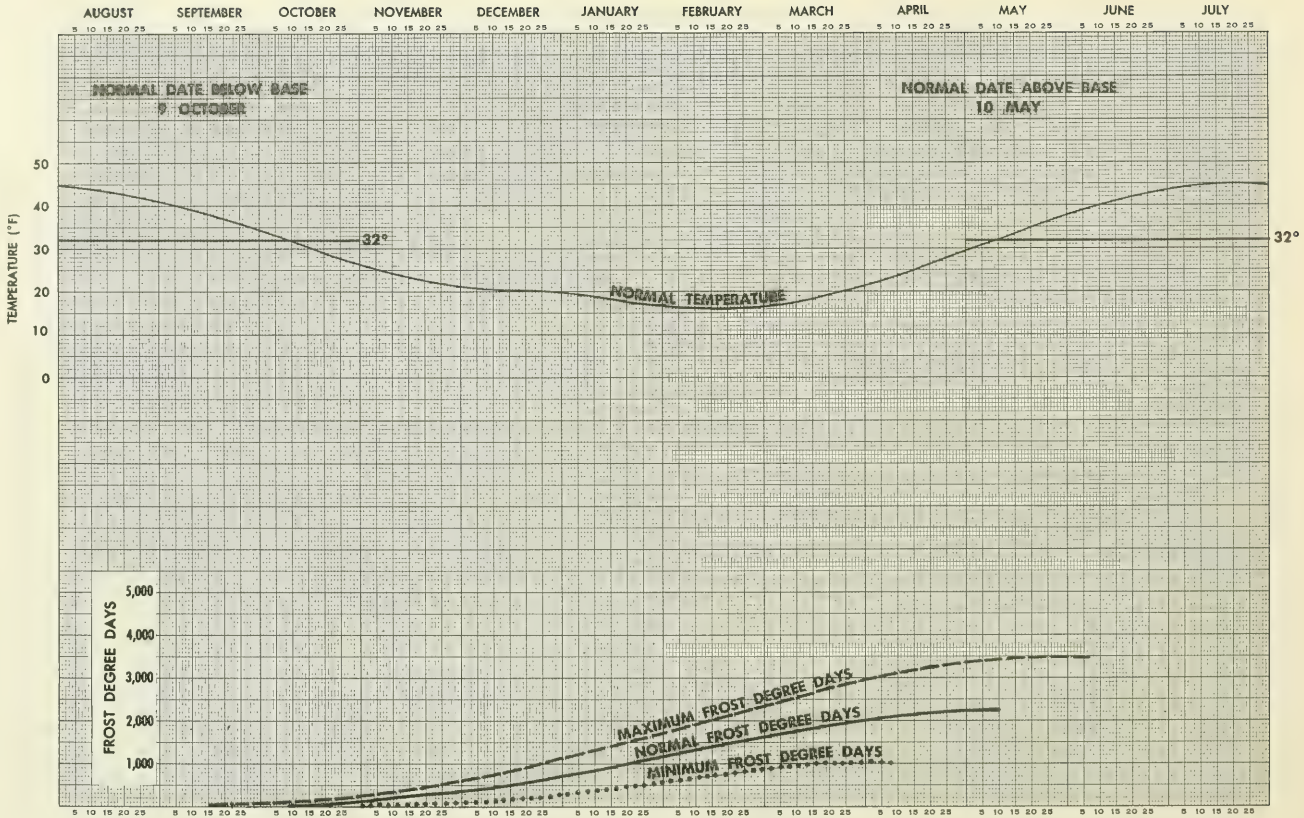

FIGURE 40A ANGMAGSSALIK (32 YEARS RECORD)

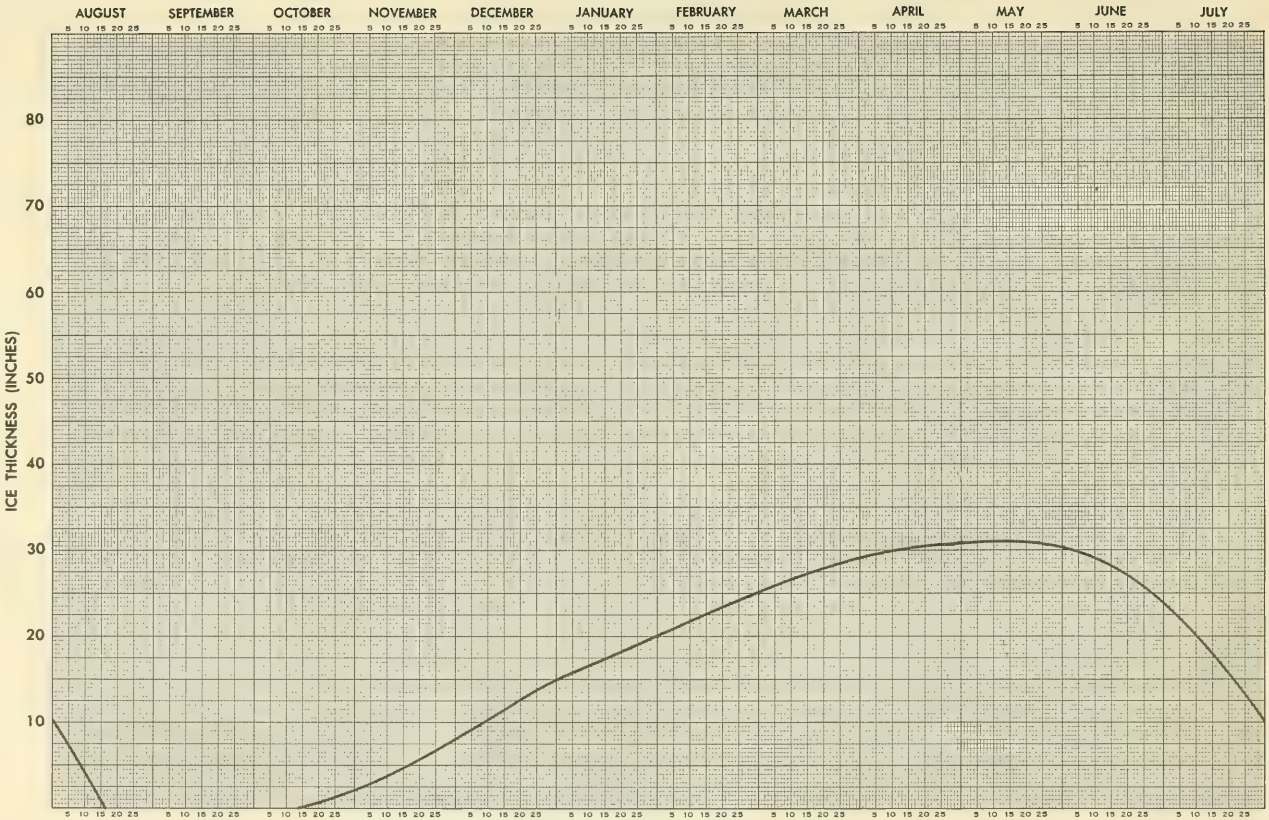

FIGURE 40B ANGMAGSSALIK THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

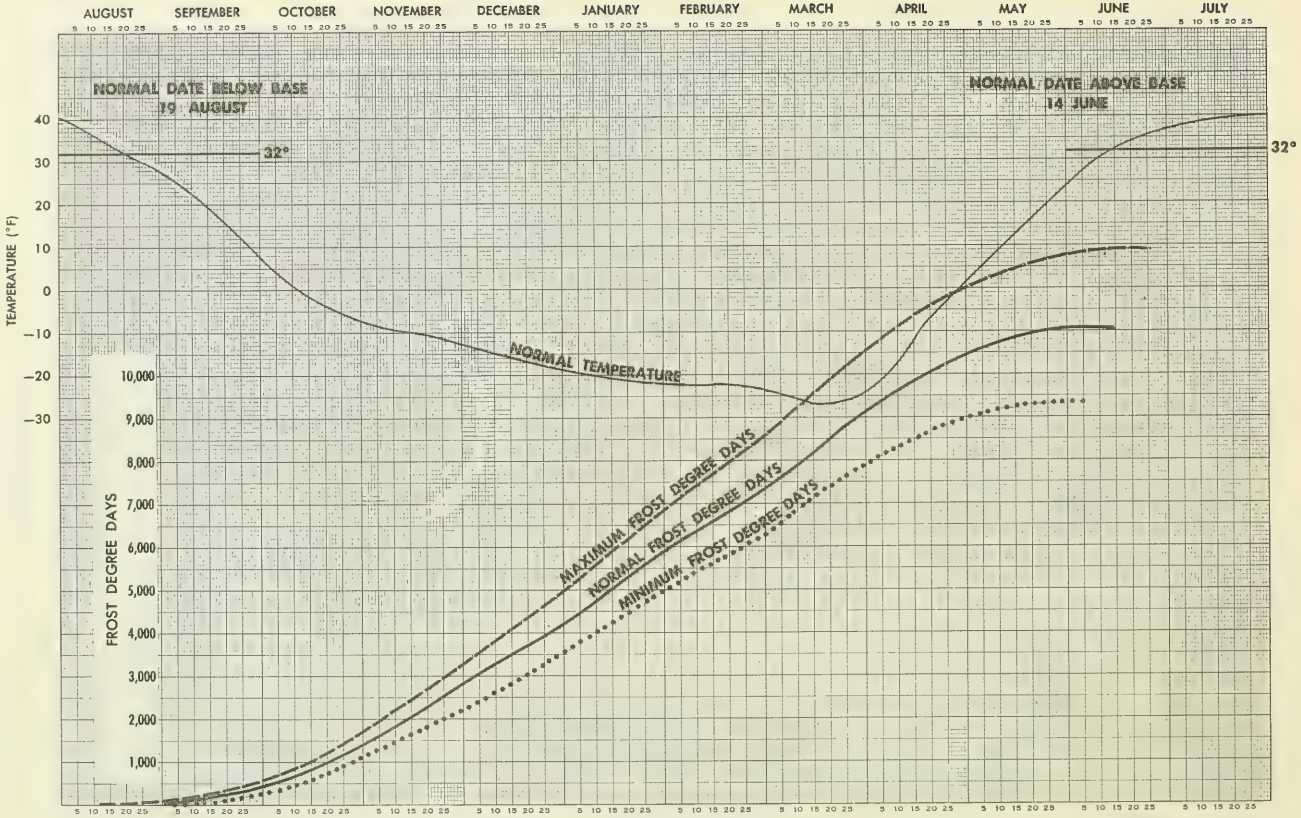

FIGURE 41A NORD (4 YEARS RECORD)

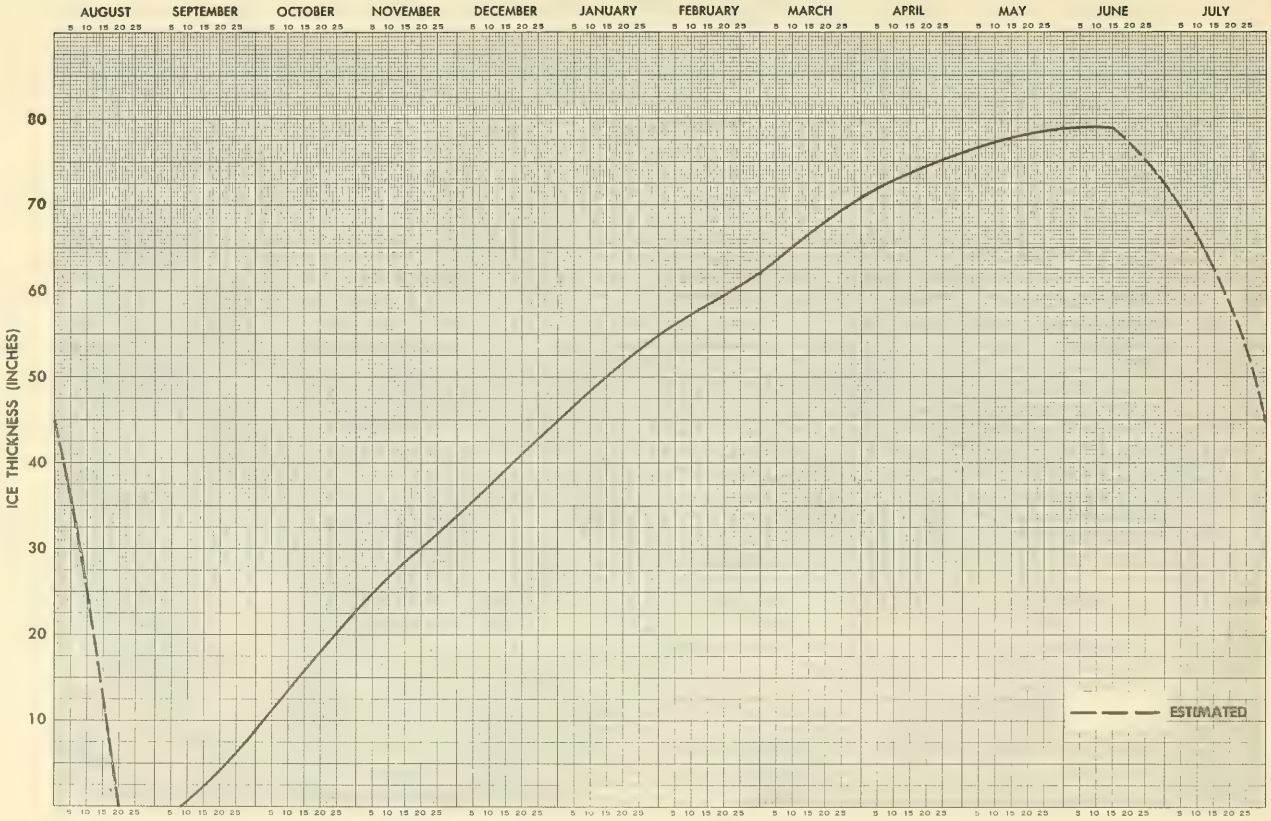

FIGURE 41B NORD THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

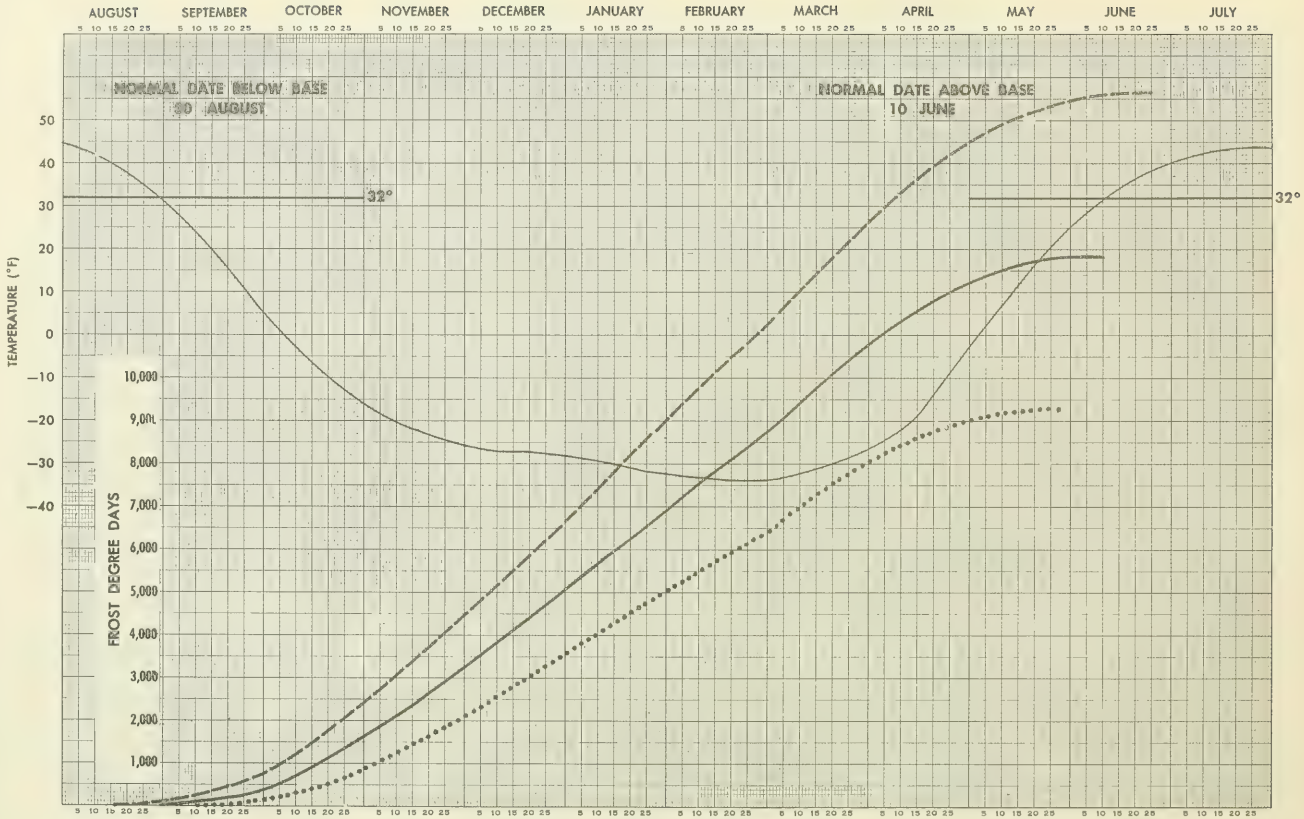

FIGURE 42A EUREKA (13 YEARS RECORD)

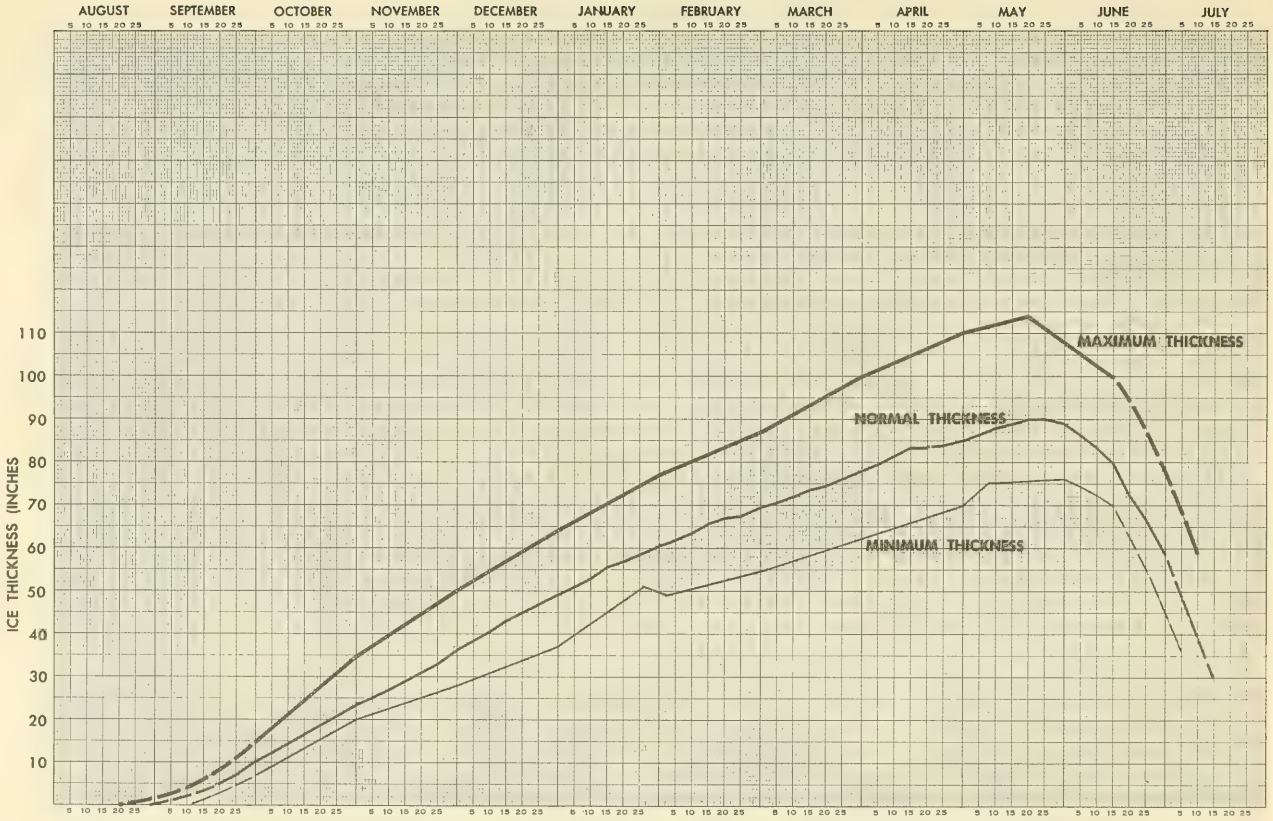

FIGURE 42B EUREKA EMPIRICAL ICE GROWTH AND DISINTEGRATION CURVE (7 YEARS RECORD)

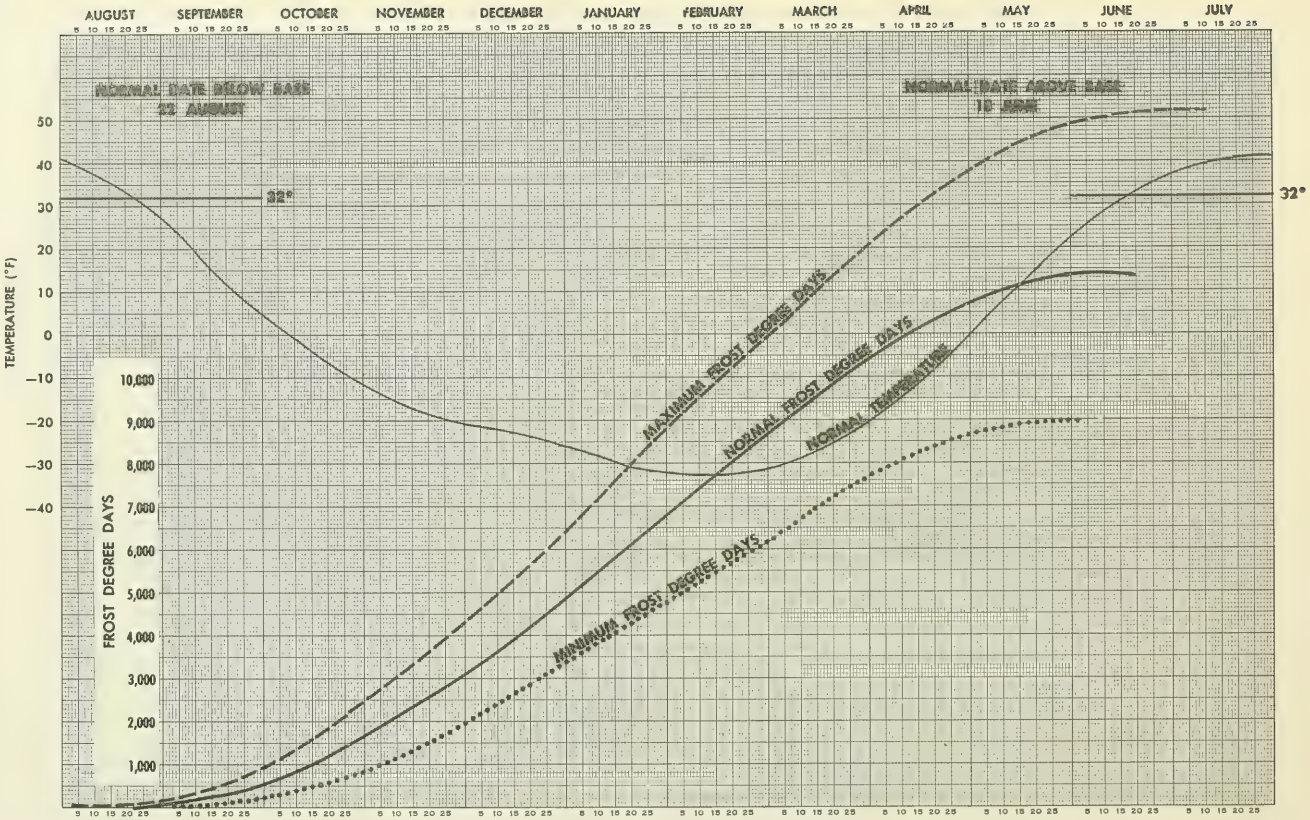

FIGURE 43A ISACHSEN (12 YEARS RECORD)

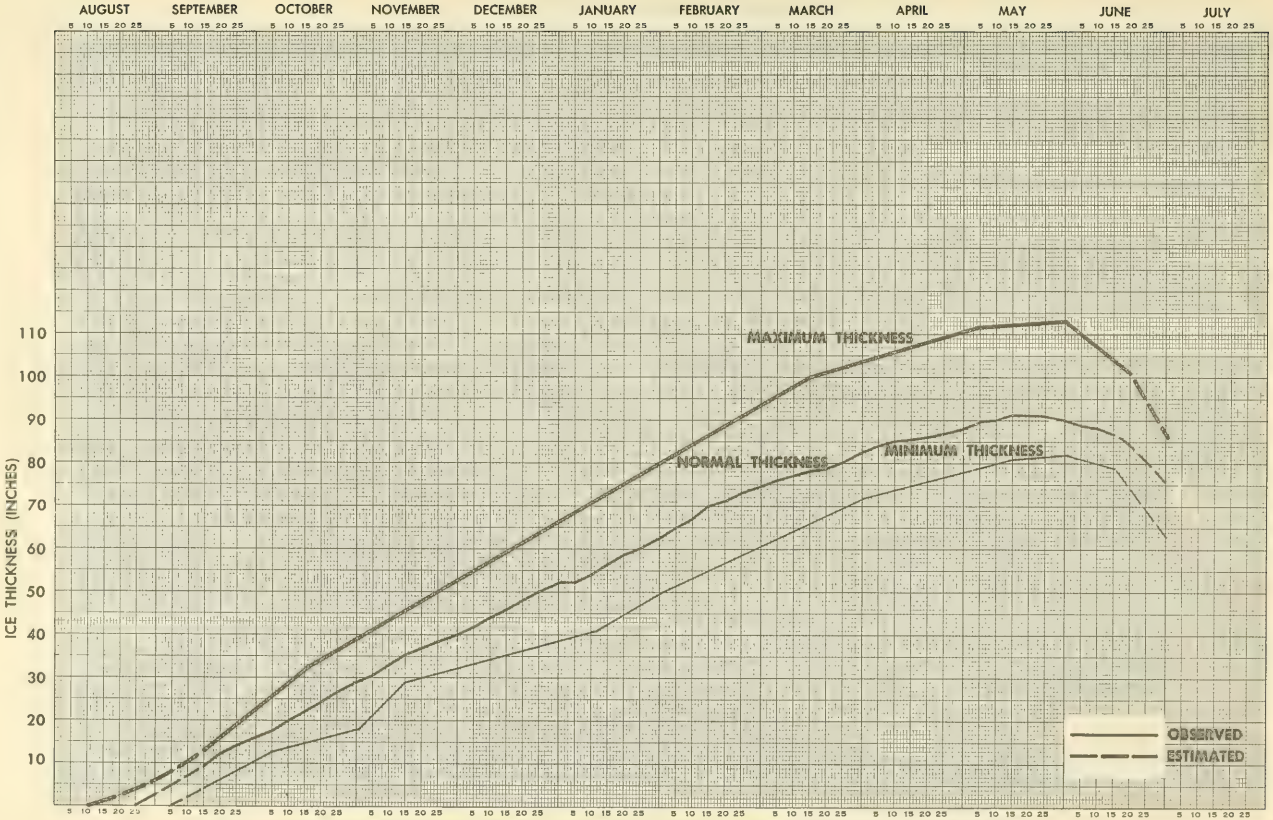

FIGURE 43B ISACHSEN EMPIRICAL ICE GROWTH AND DISINTEGRATION CURVE (14 YEARS RECORD)

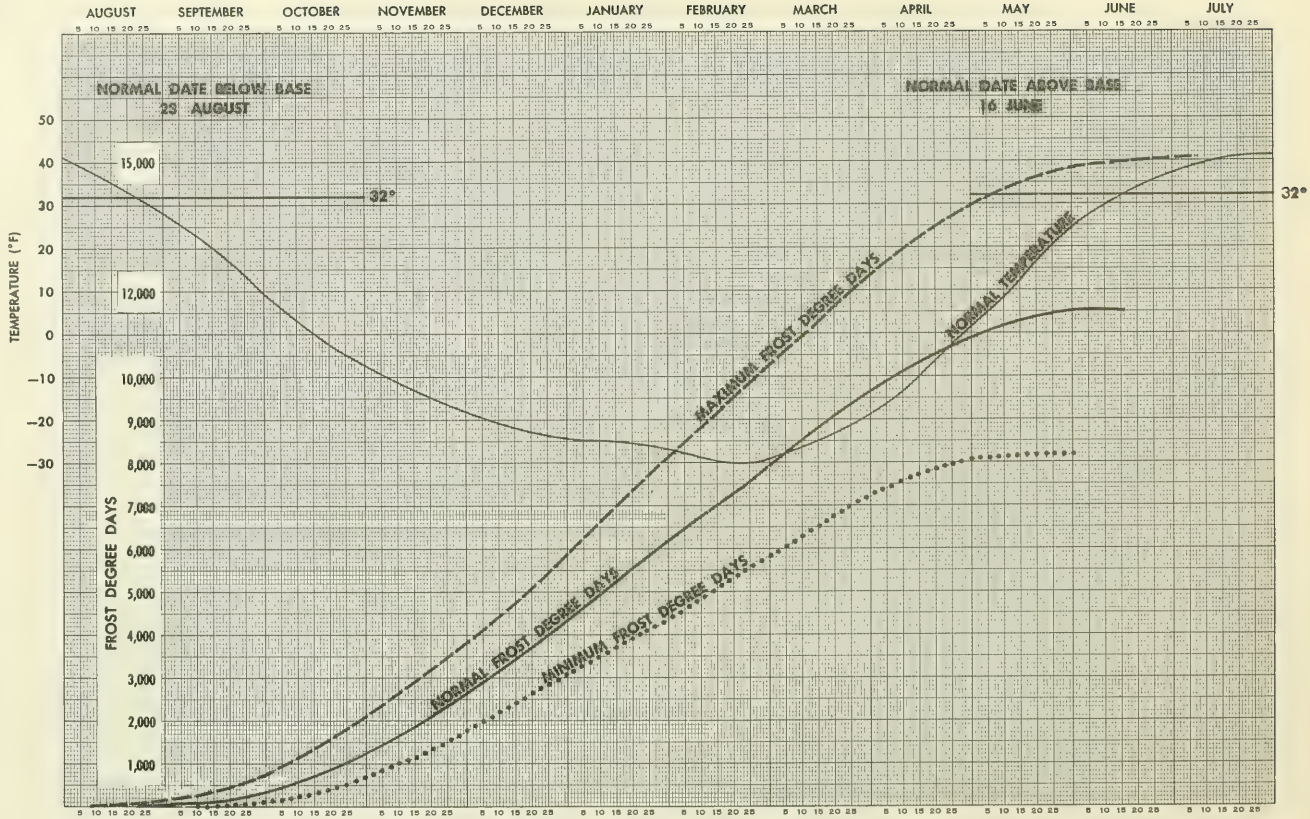

FIGURE 44A MOULD BAY (12 YEARS RECORD)

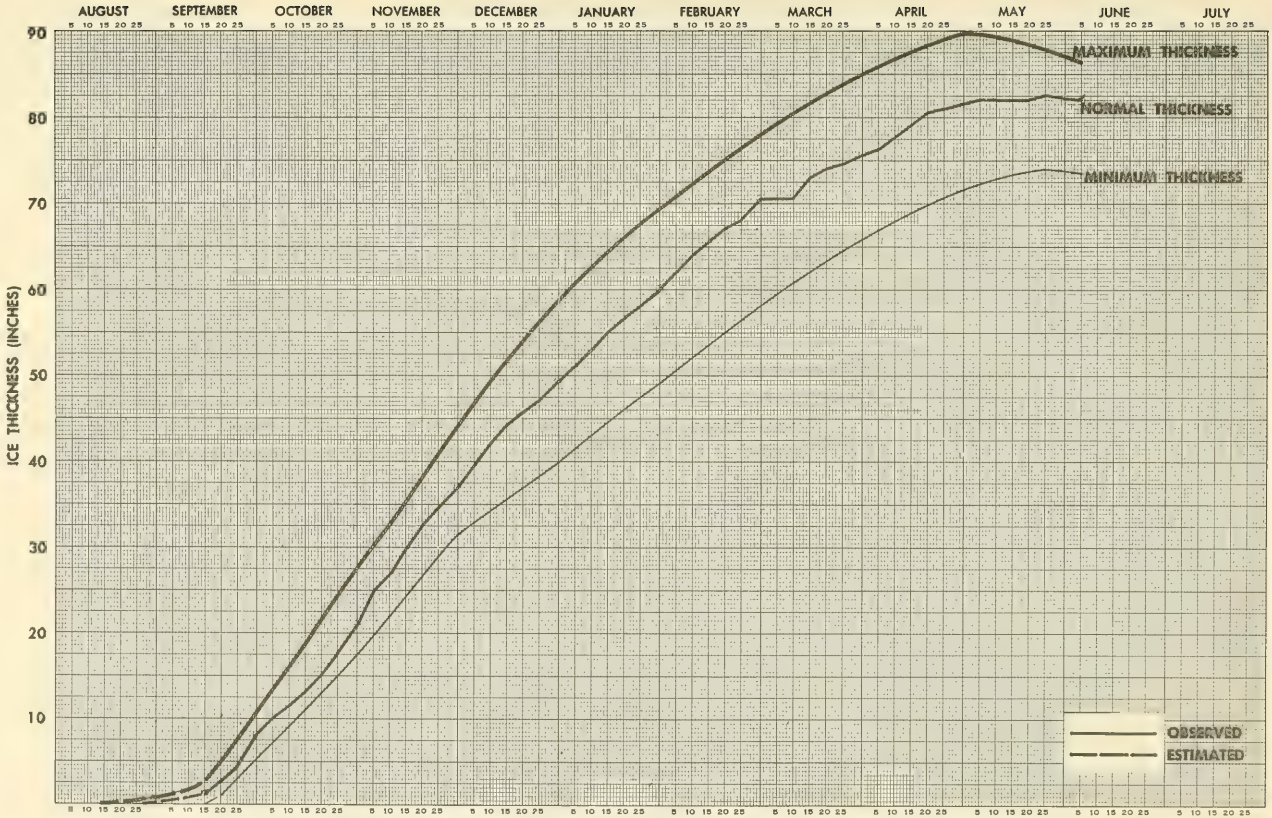

FIGURE 44B MOULD BAY EMPIRICAL ICE GROWTH AND DISINTEGRATION CURVE (10 YEARS RECORD)

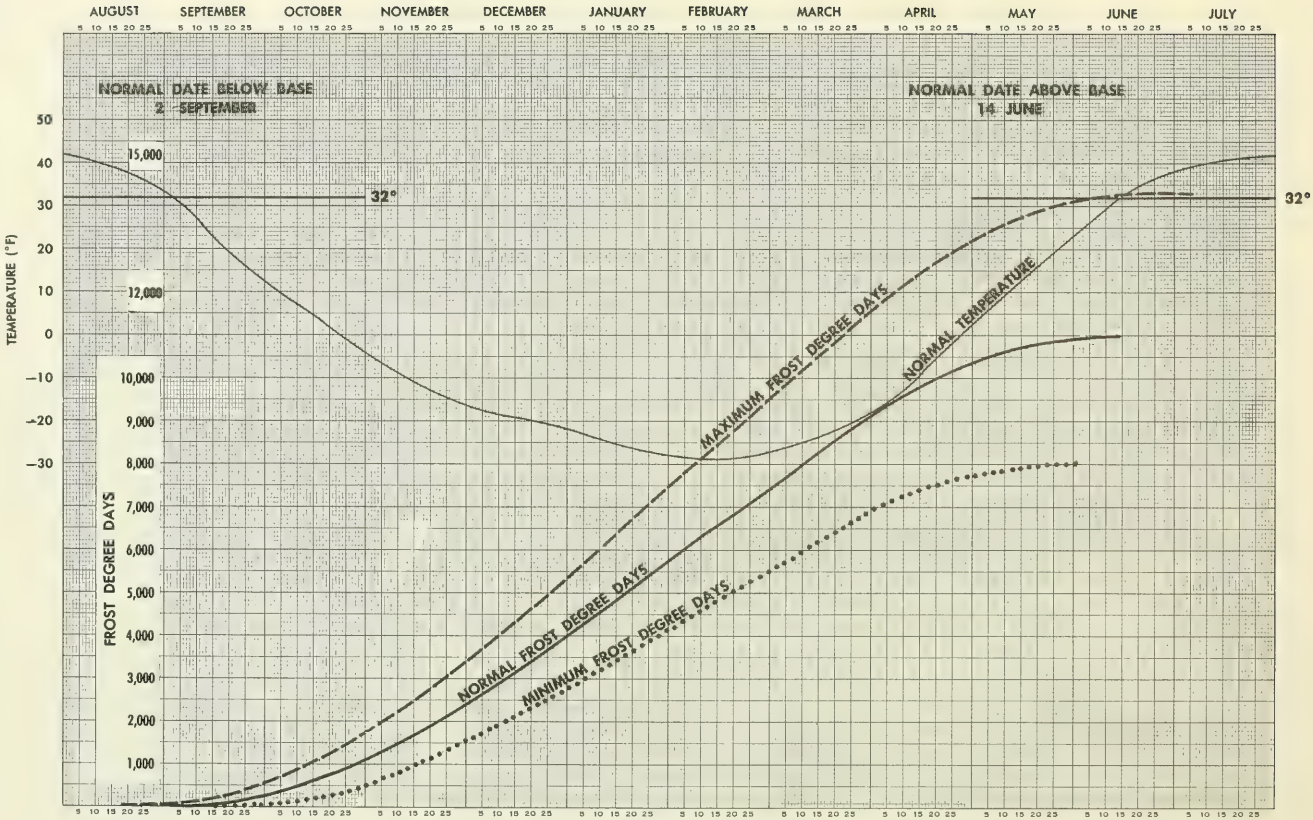

FIGURE 45A RESOLUTE BAY (13 YEARS RECORD)

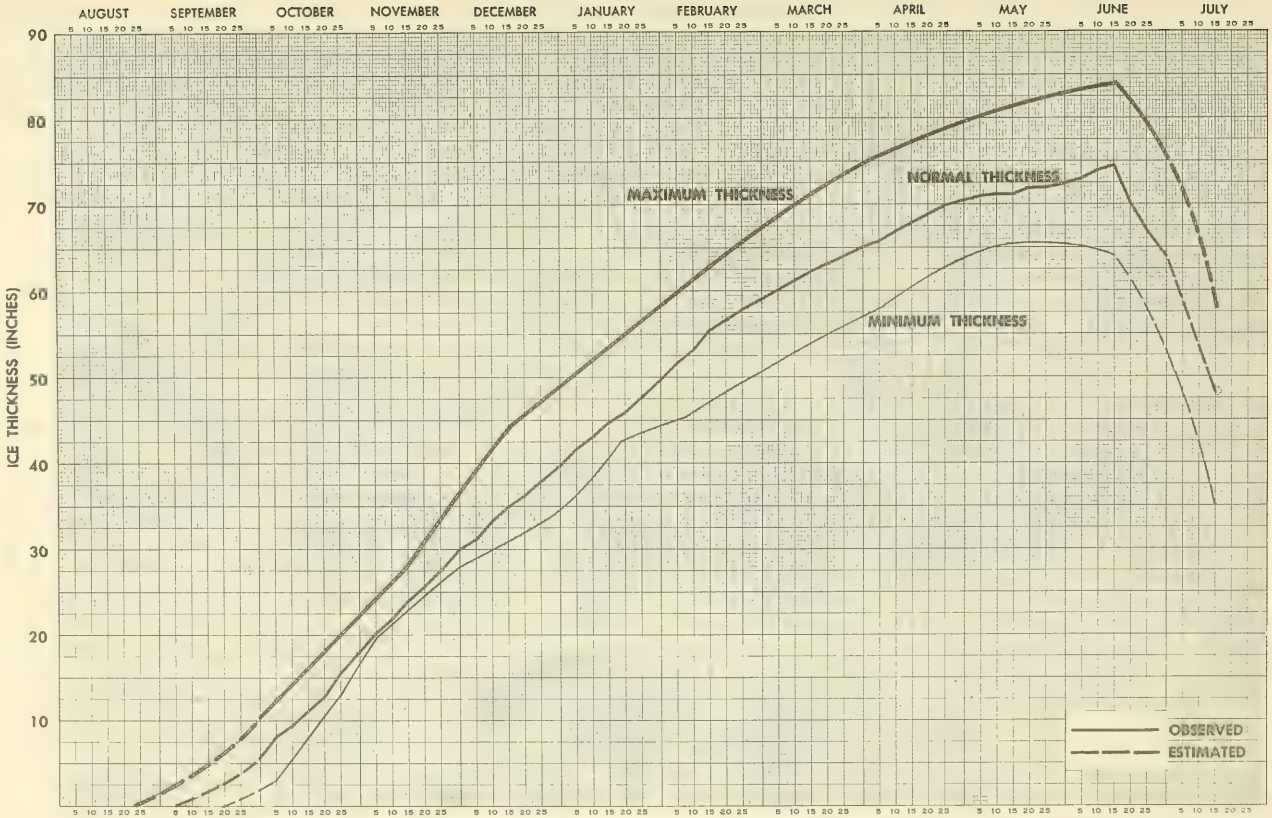

FIGURE 45B RESOLUTE BAY EMPIRICAL ICE GROWTH AND DISINTEGRATION CURVE (15 YEARS RECORD)

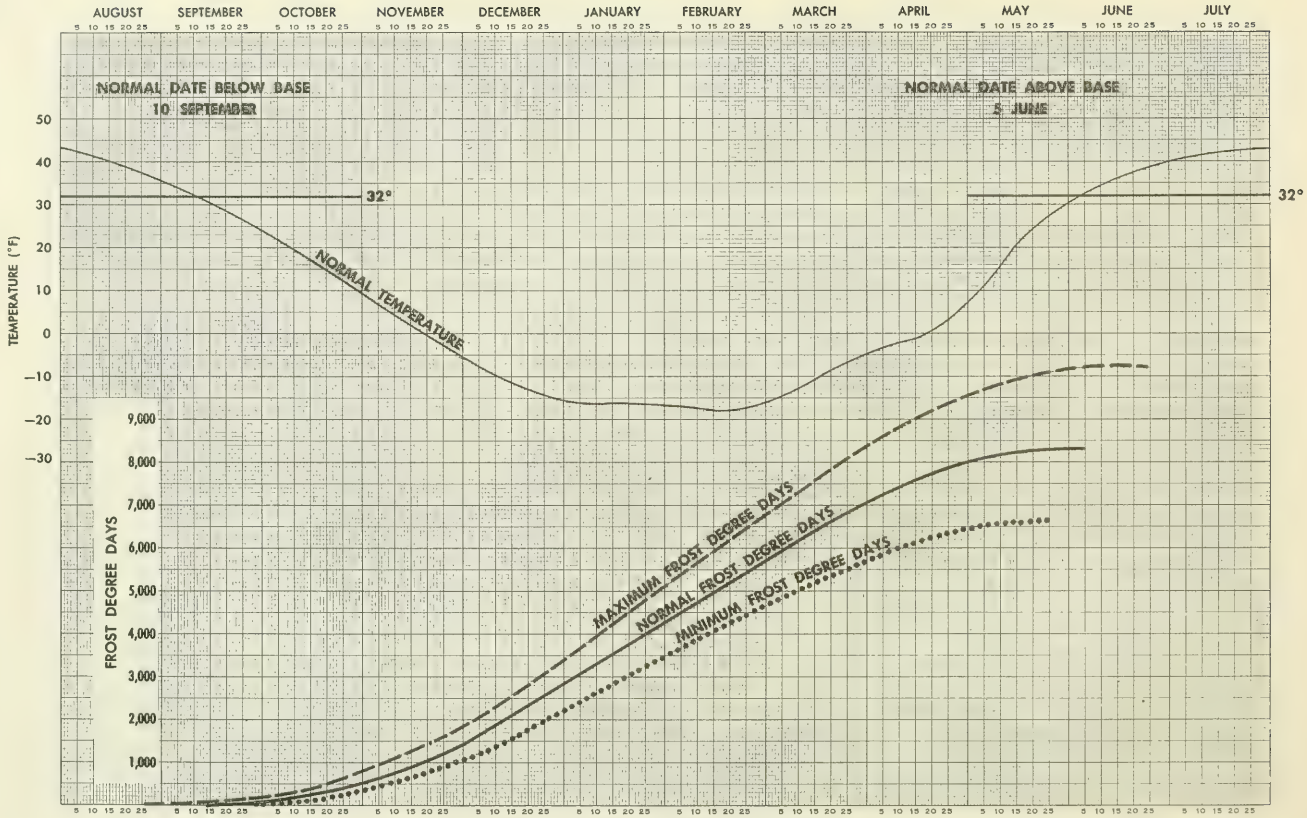

FIGURE 46A DUNDAS HARBOR (7 YEARS RECORD)

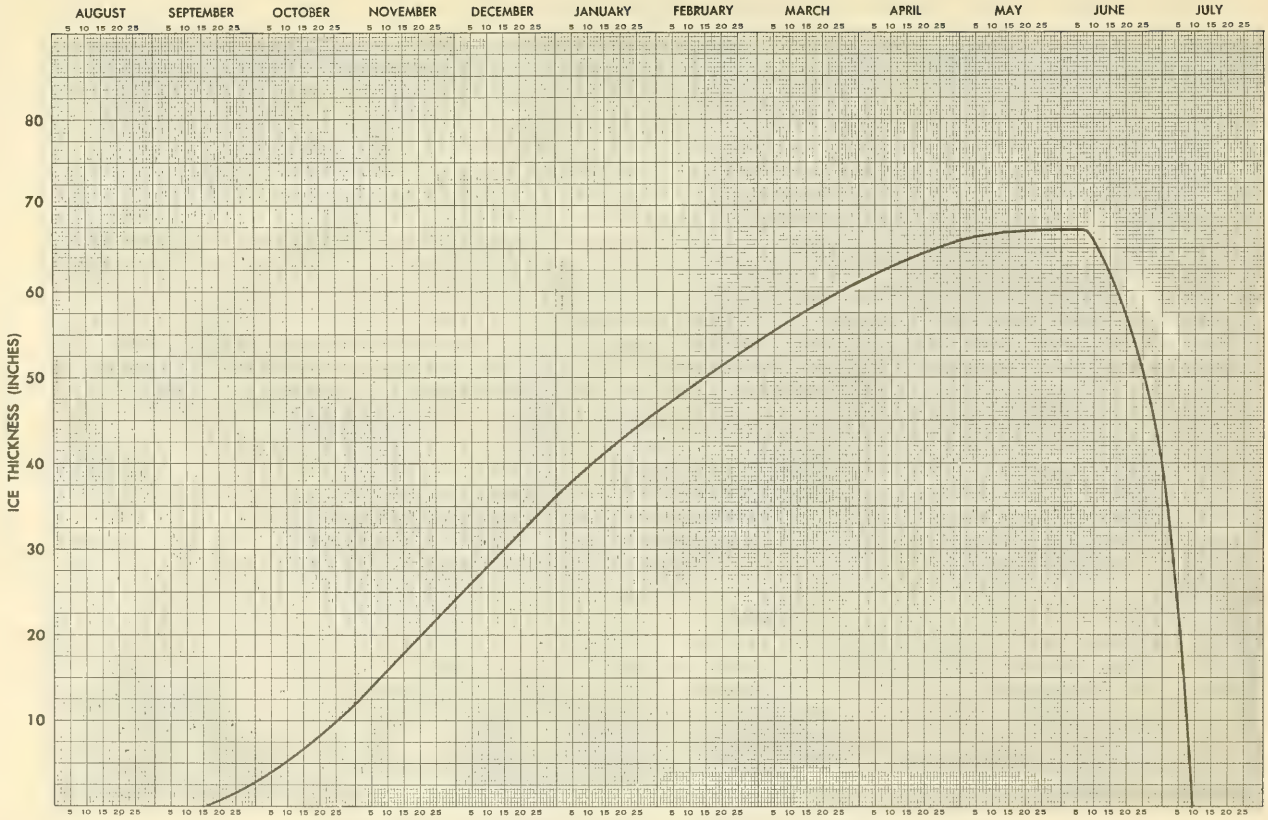

FIGURE 46B DUNDAS HARBOR THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

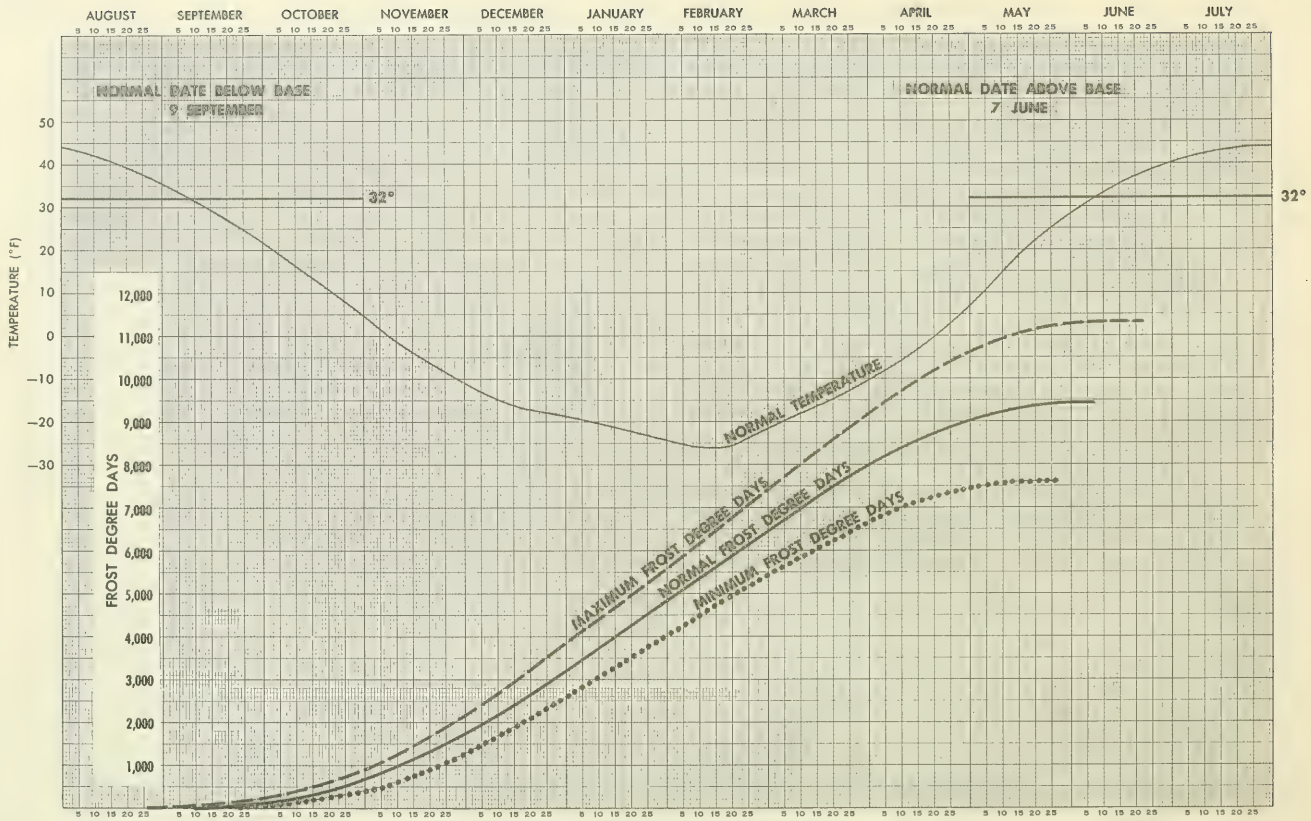

FIGURE 47A ARCTIC BAY (13 YEARS RECORD)

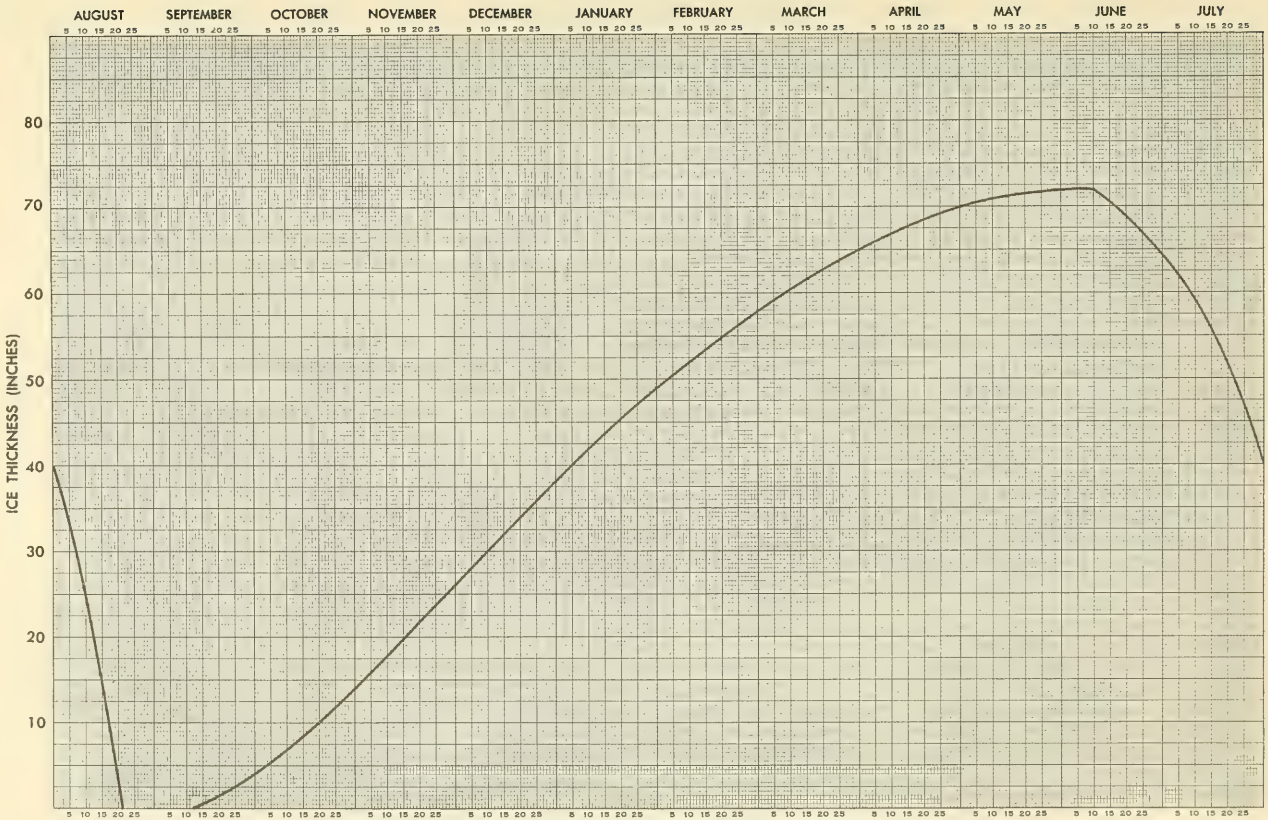

FIGURE 47B ARCTIC BAY THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

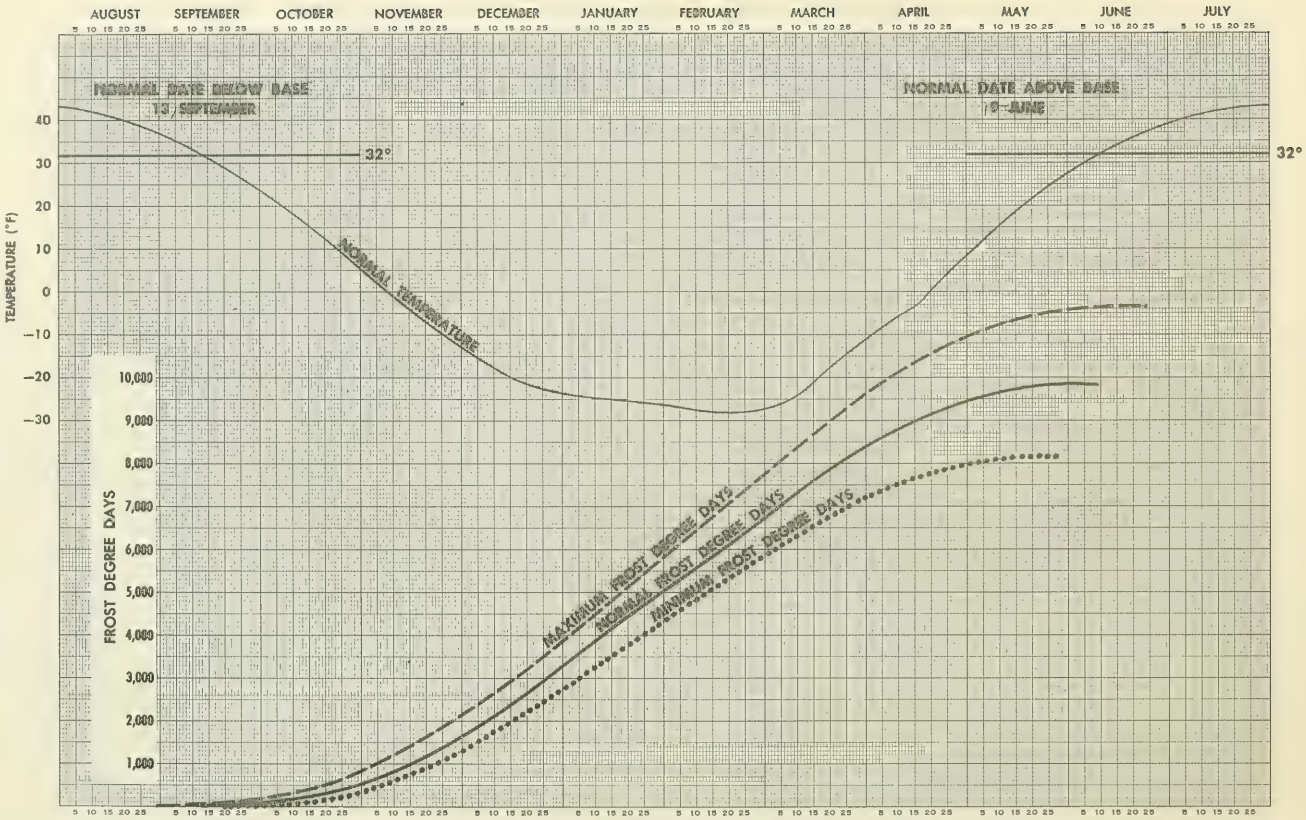

FIGURE 48A POND INLET (24 YEARS RECORD)

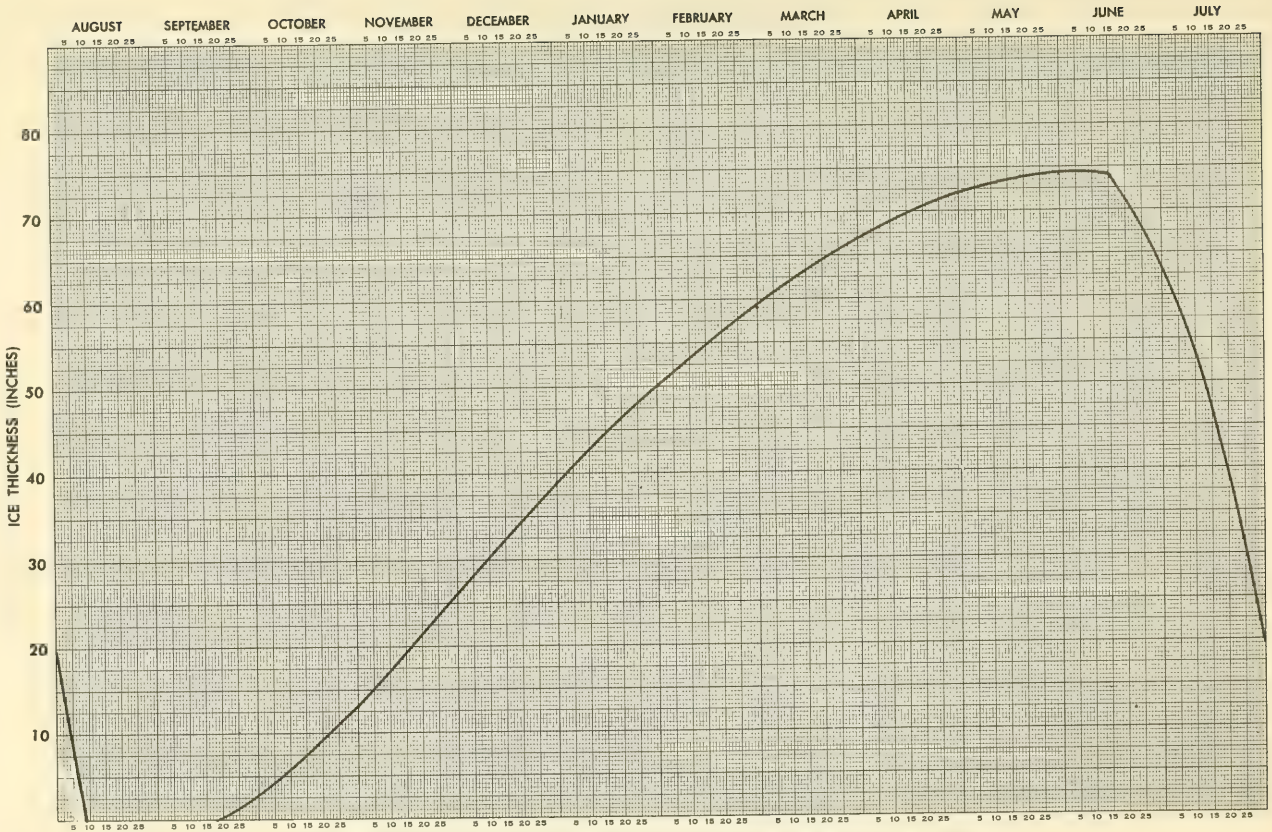

FIGURE 48B POND INLET THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

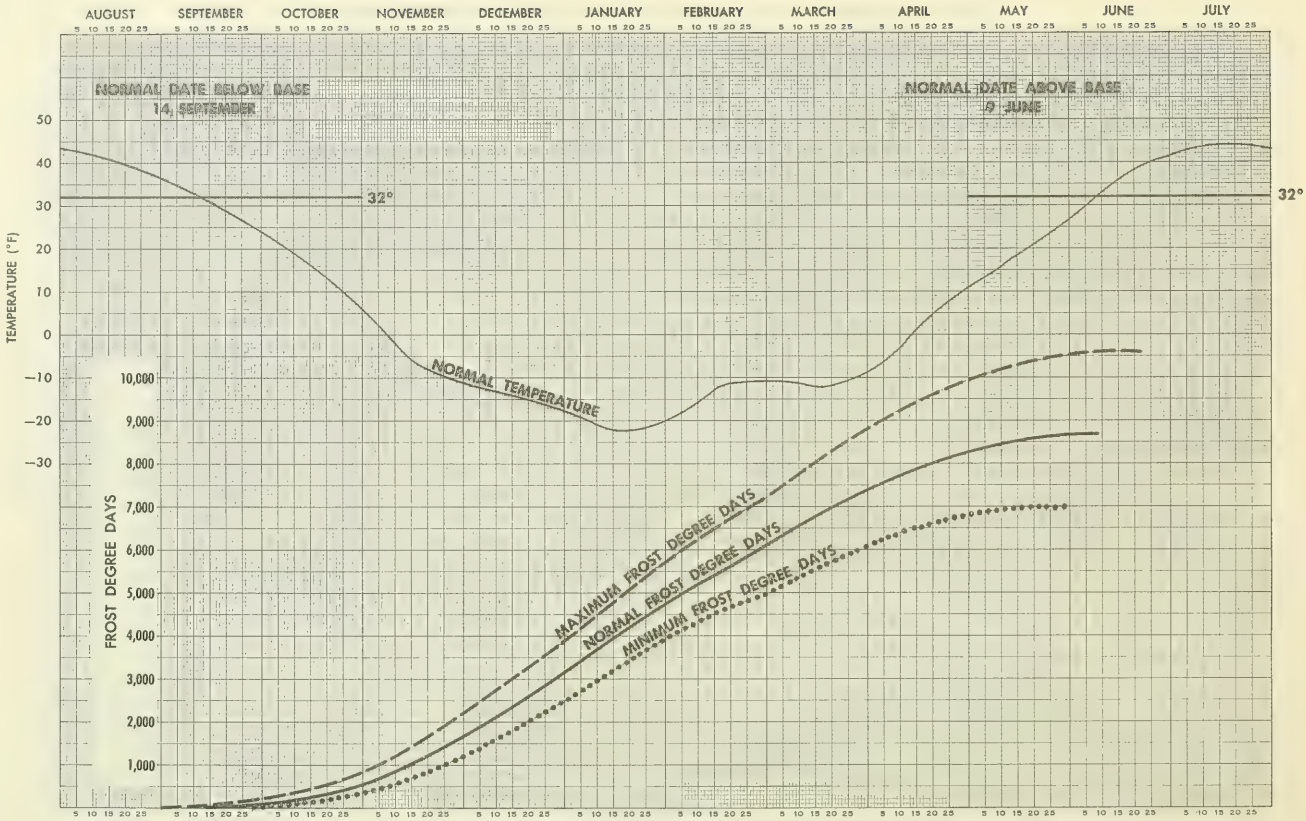

FIGURE 49A HERSCHEL ISLAND (7 YEARS RECORD)

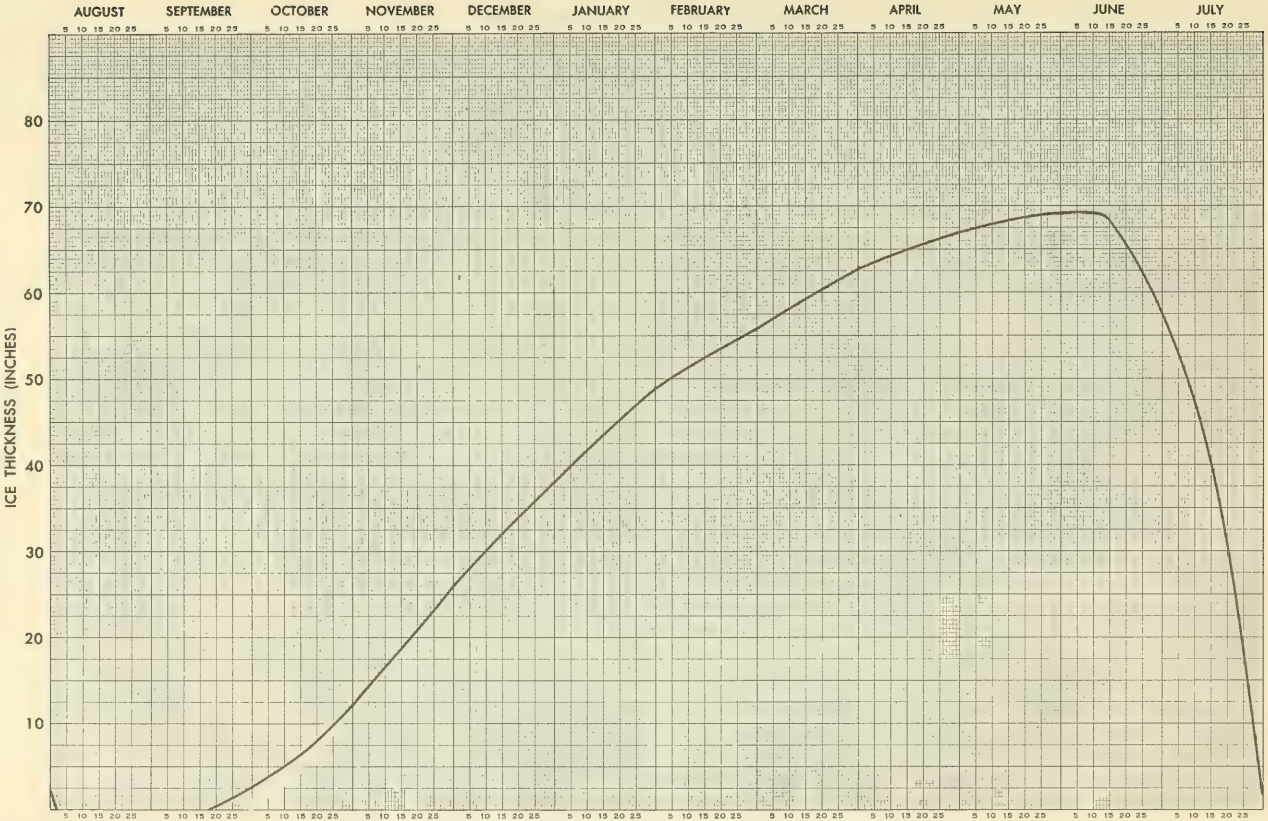

FIGURE 49B HERSCHEL ISLAND THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

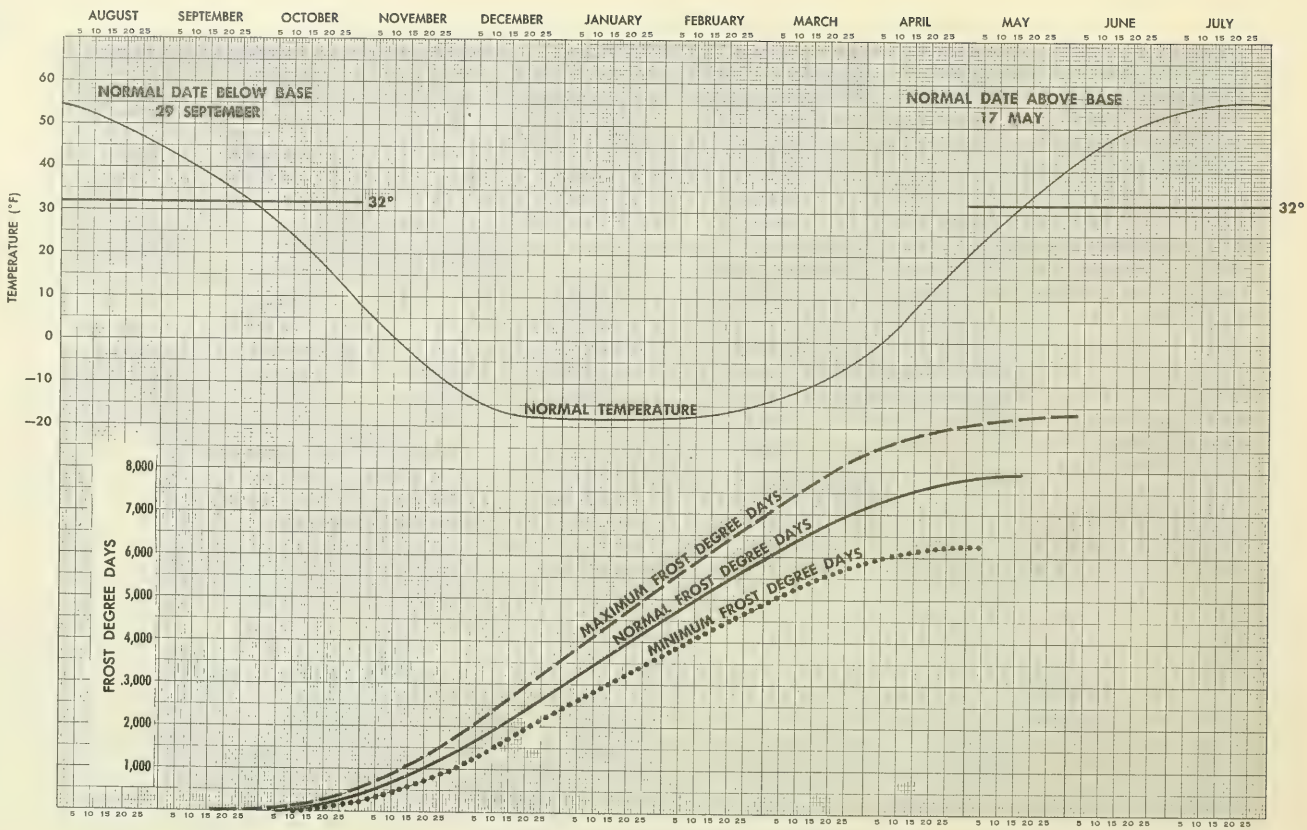

FIGURE 50A AKLAVIK (25 YEARS RECORD)

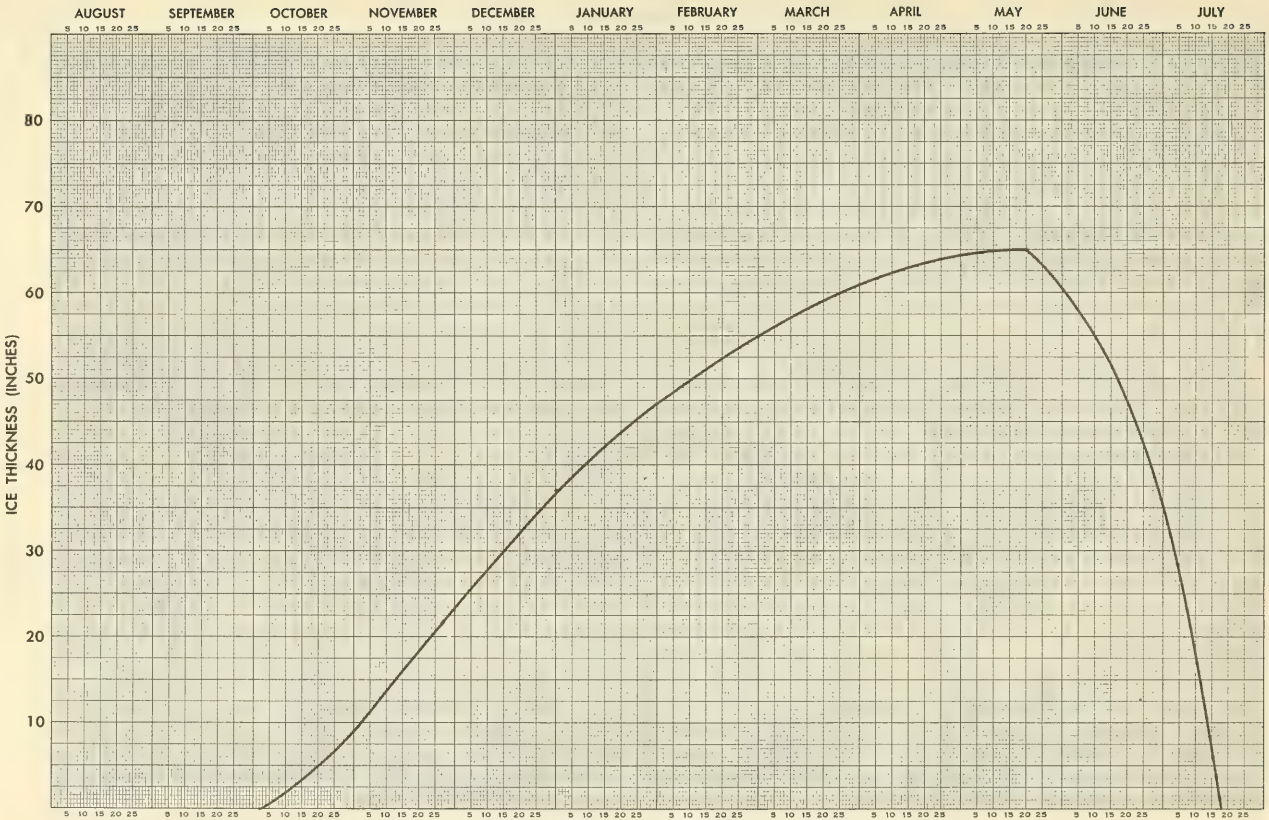

FIGURE 50B AKLAVIK THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

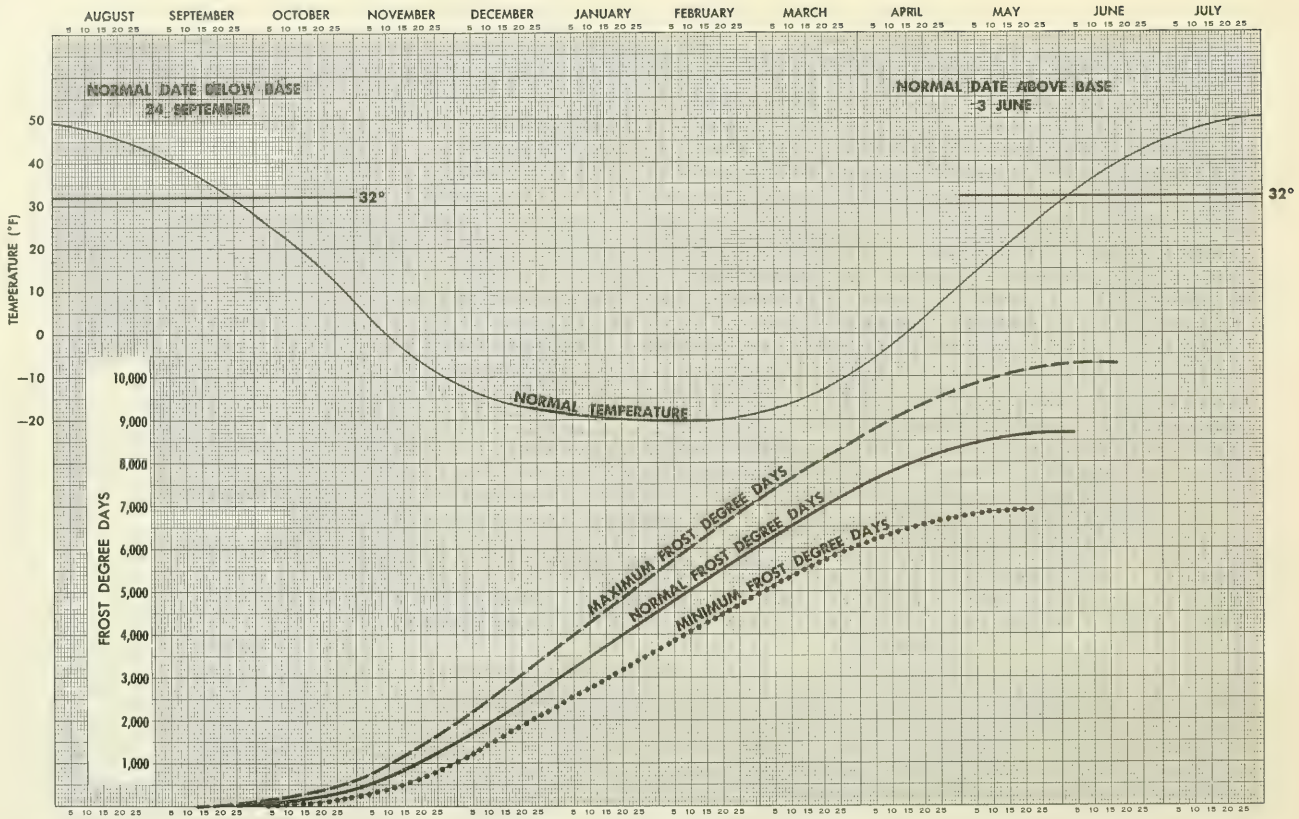

FIGURE 51A COPPERMINE (30 YEARS RECORD)

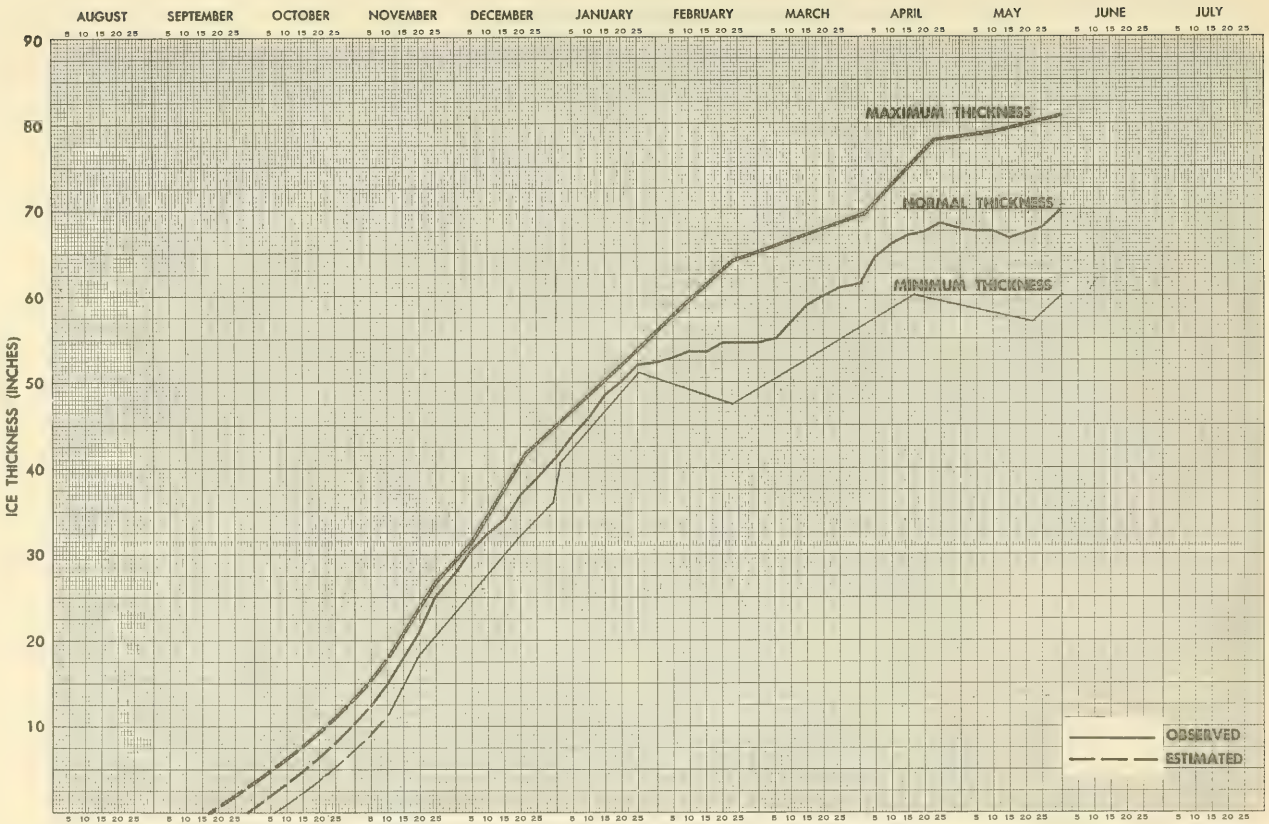

FIGURE 51B COPPERMINE EMPIRICAL ICE GROWTH CURVE (4 YEARS RECORD)

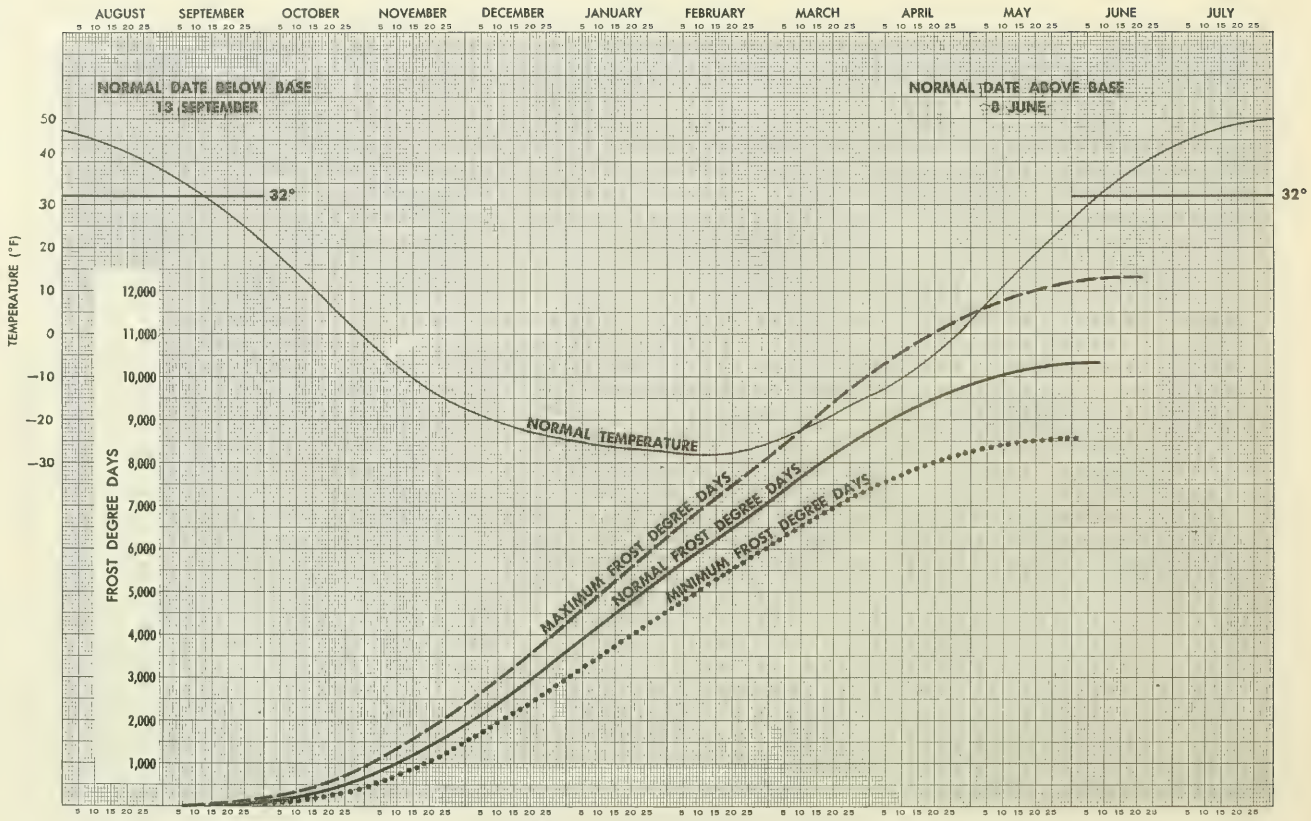

FIGURE 52A CAMBRIDGE BAY (14 YEARS RECORD)

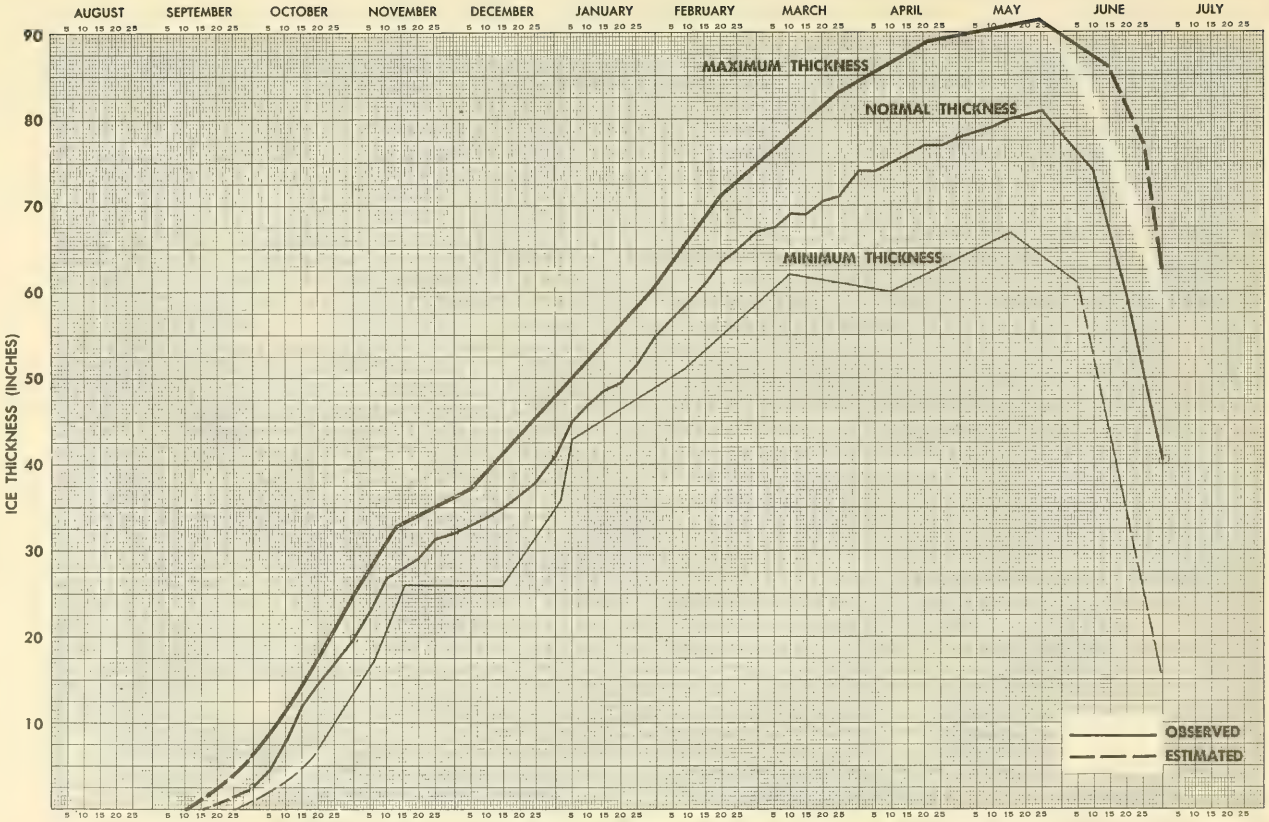

FIGURE 52B CAMBRIDGE BAY EMPIRICAL ICE GROWTH AND DISINTEGRATION CURVE (3 YEARS RECORD)

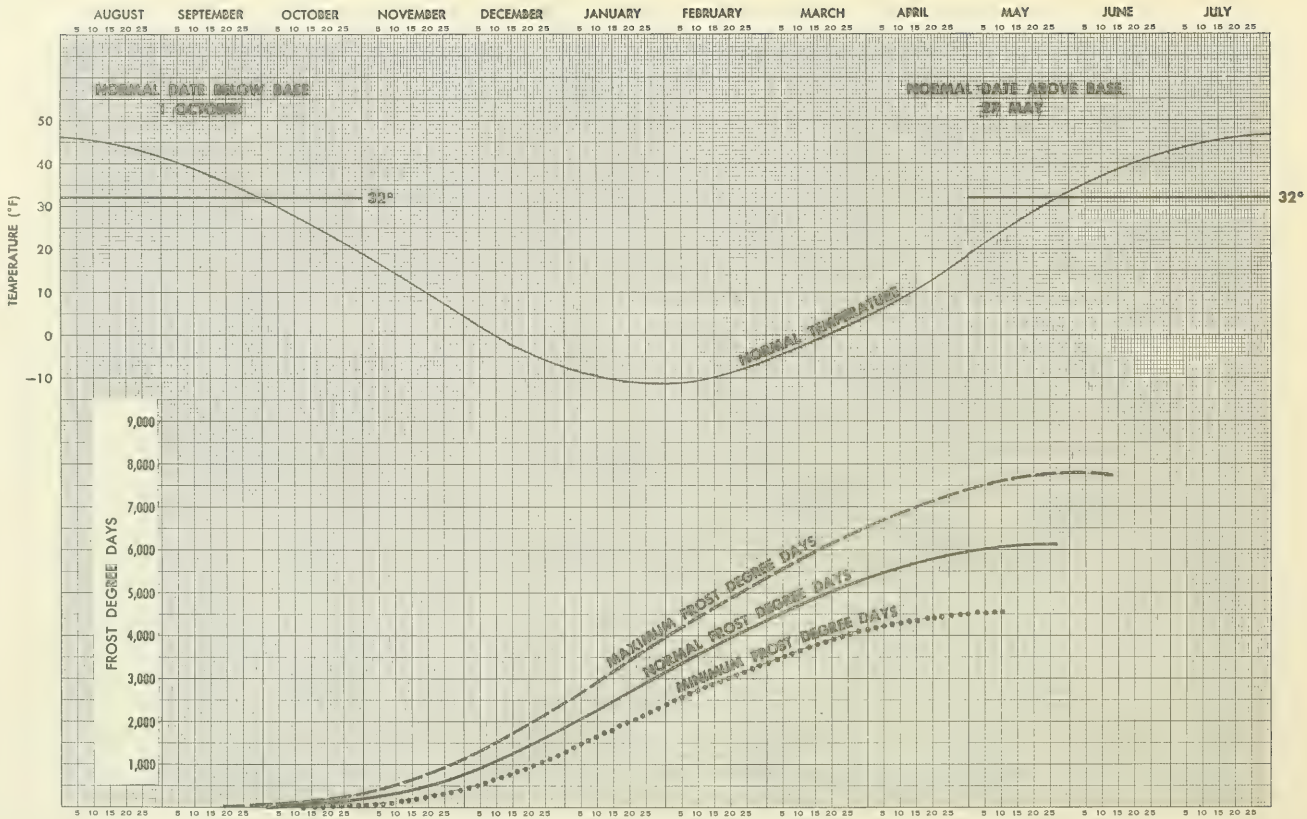

FIGURE 53A LAKE HARBOUR (19 YEARS RECORD)

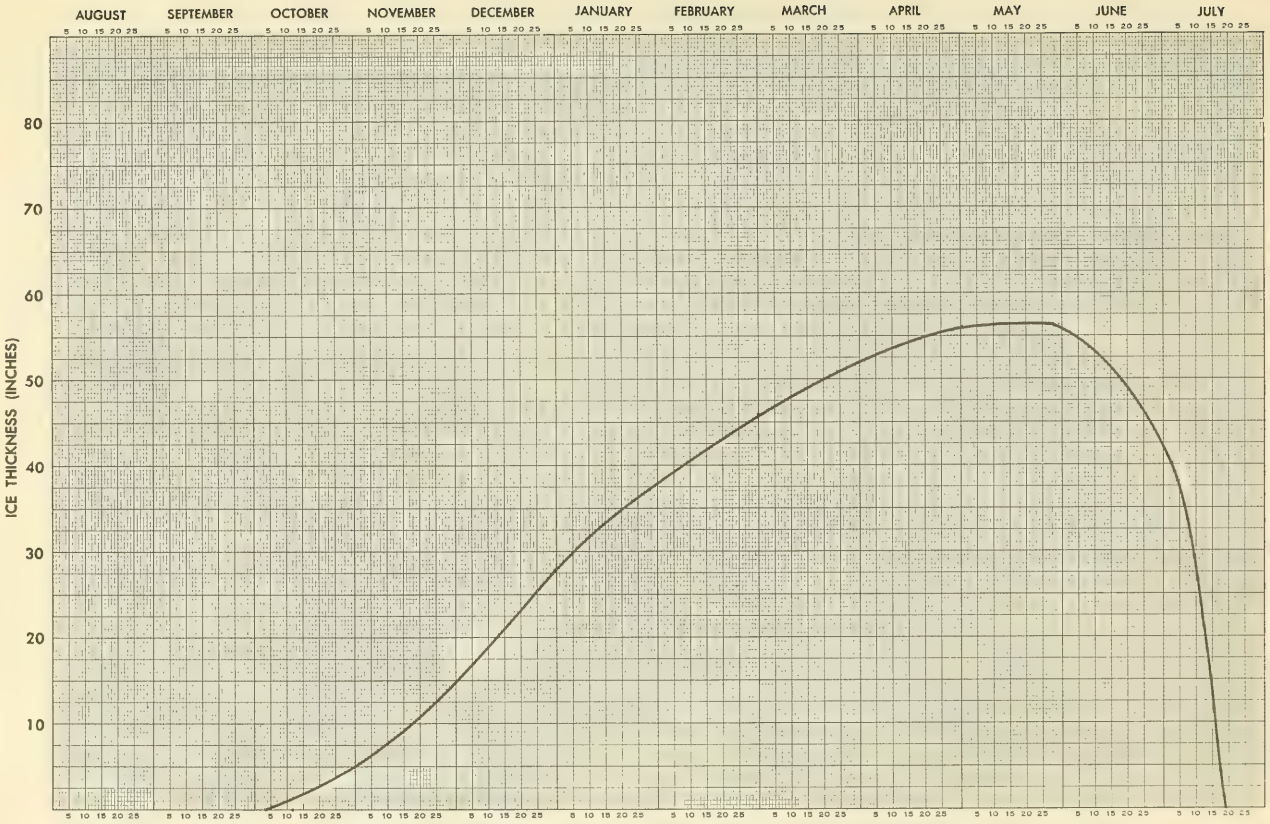

FIGURE 53B LAKE HARBOUR THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

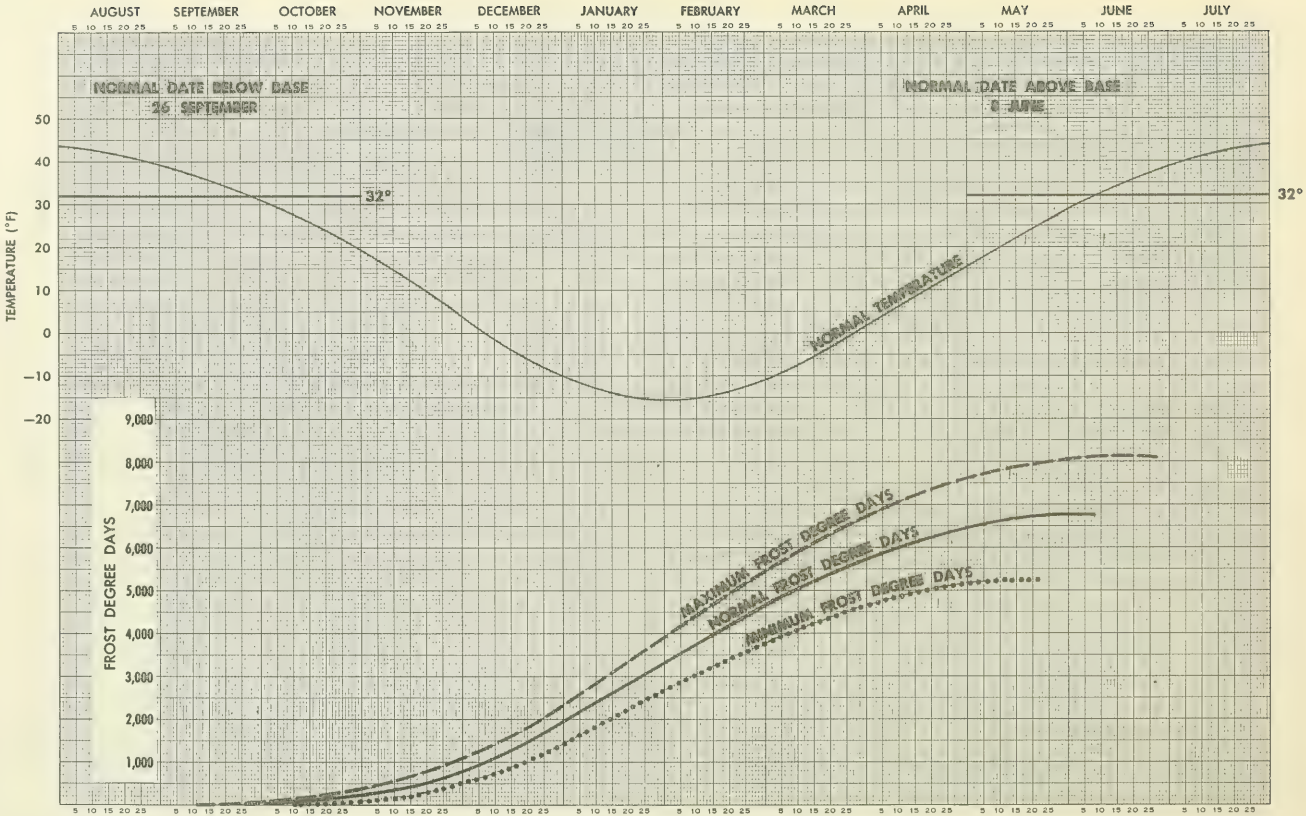

FIGURE 54A NOTTINGHAM ISLAND (22 YEARS RECORD)

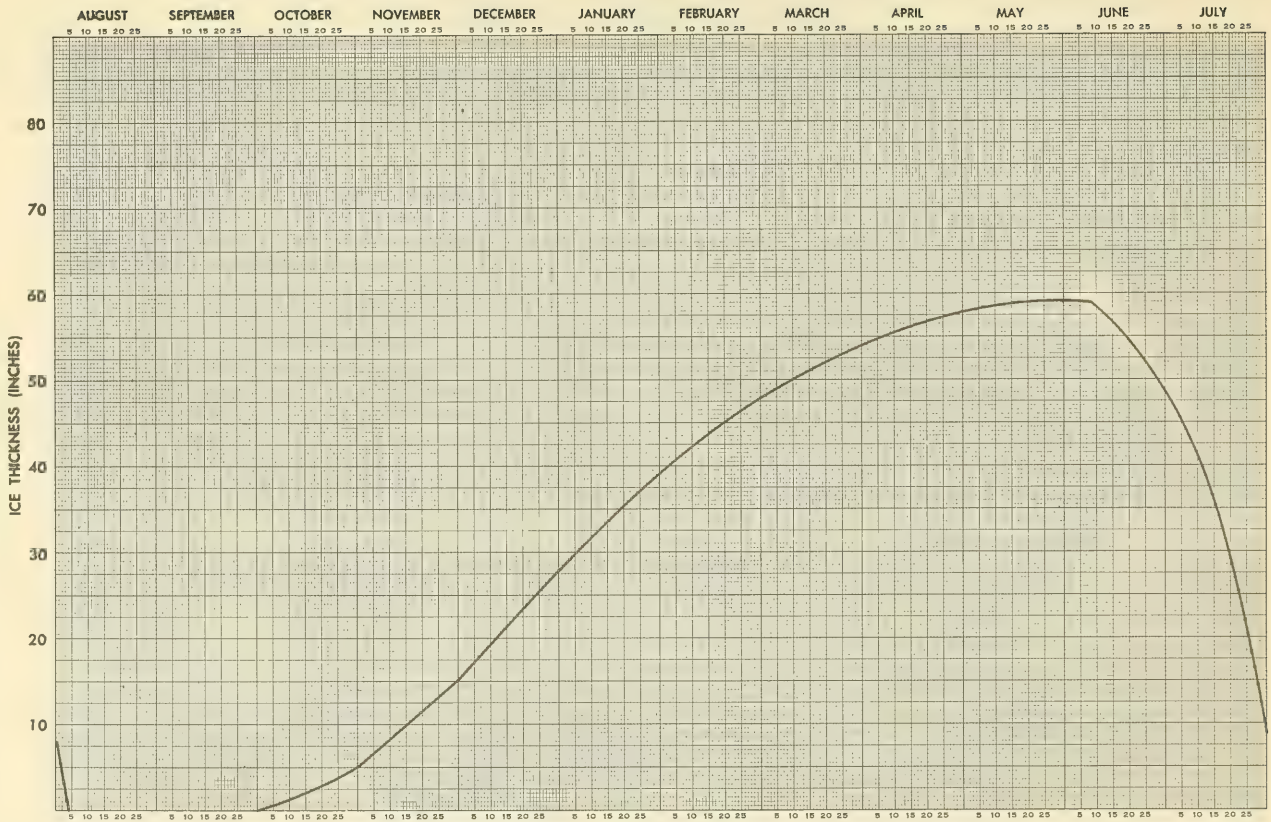

FIGURE 54B NOTTINGHAM ISLAND THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

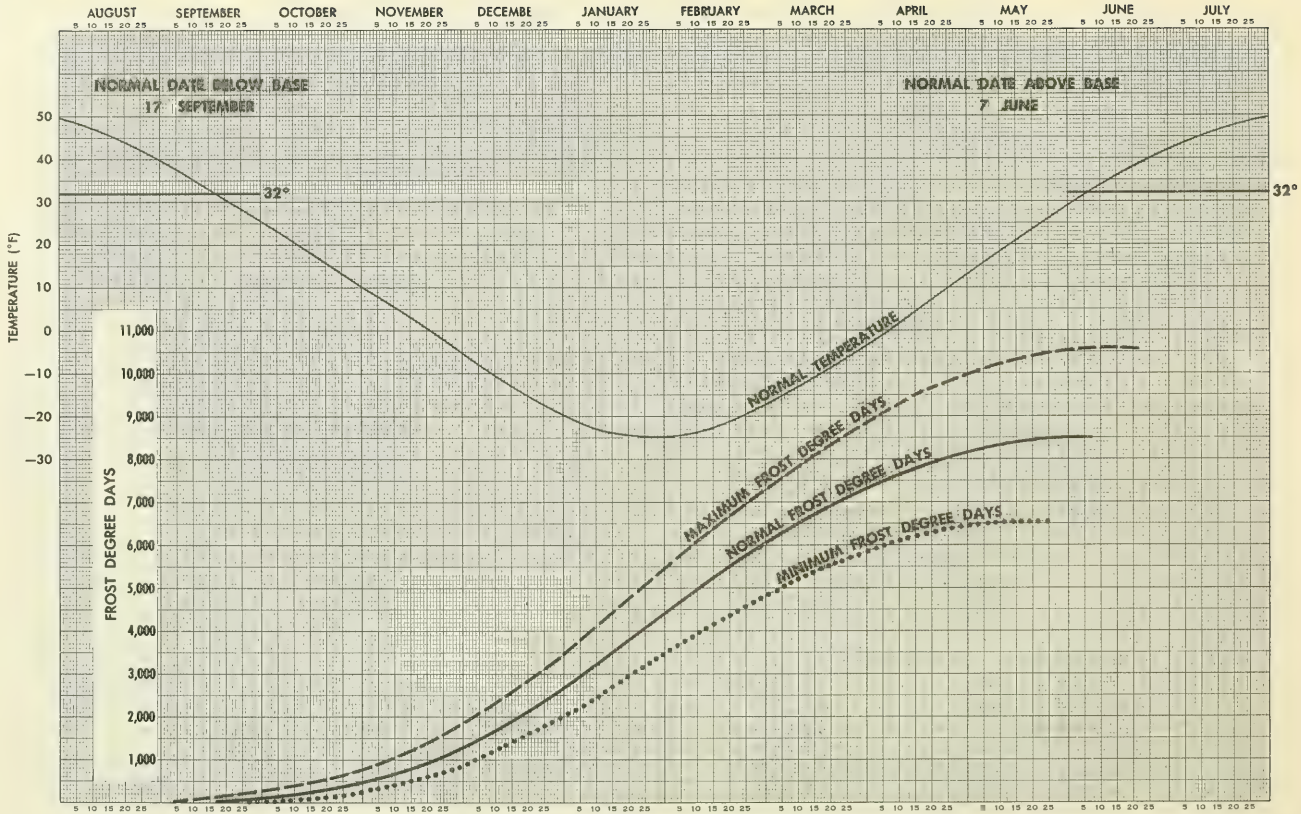

FIGURE 55A CORAL HARBOR (11 YEARS RECORD)

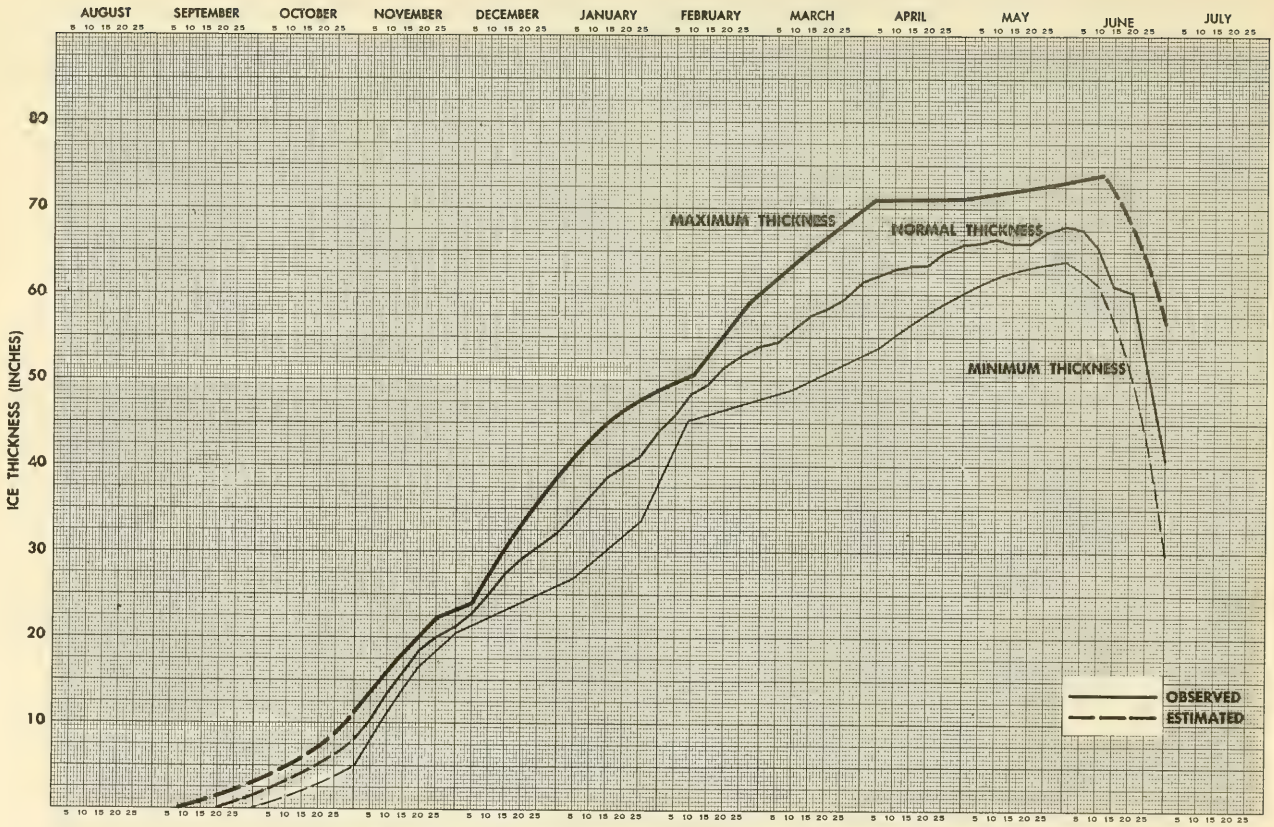

FIGURE 55B CORAL HARBOR EMPIRICAL ICE GROWTH AND DISINTEGRATION CURVE

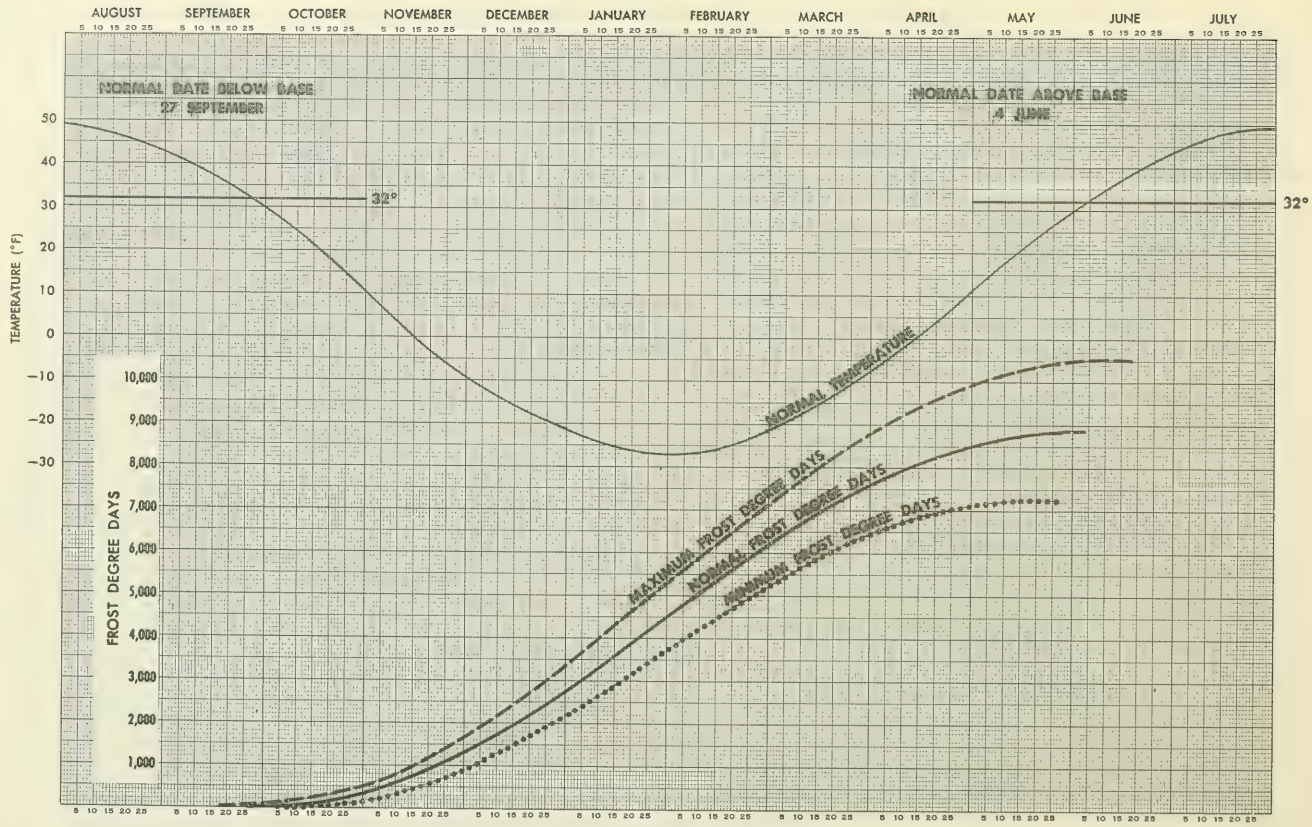

FIGURE 56A CHESTERFIELD (29 YEARS RECORD)

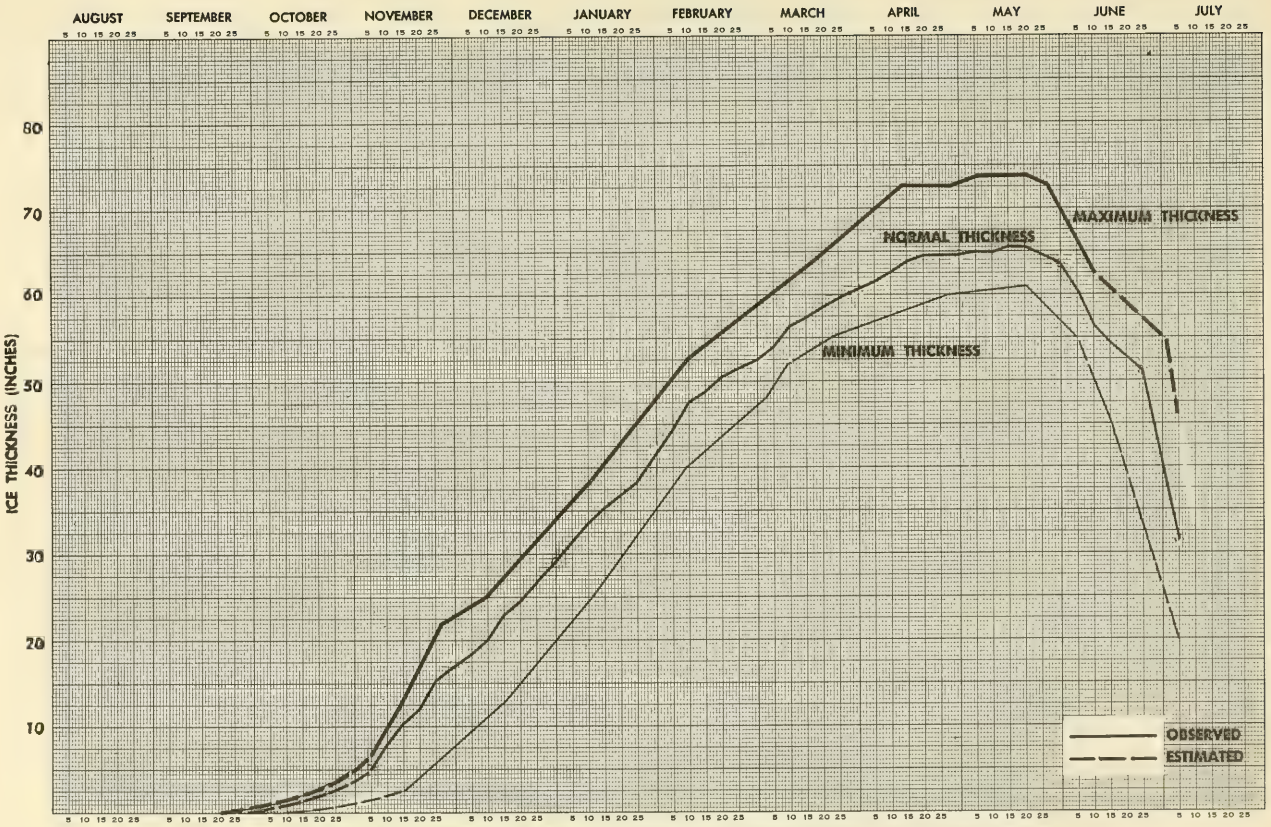

FIGURE 56B CHESTERFIELD EMPIRICAL ICE GROWTH AND DISINTEGRATION CURVE (3 YEARS RECORD)

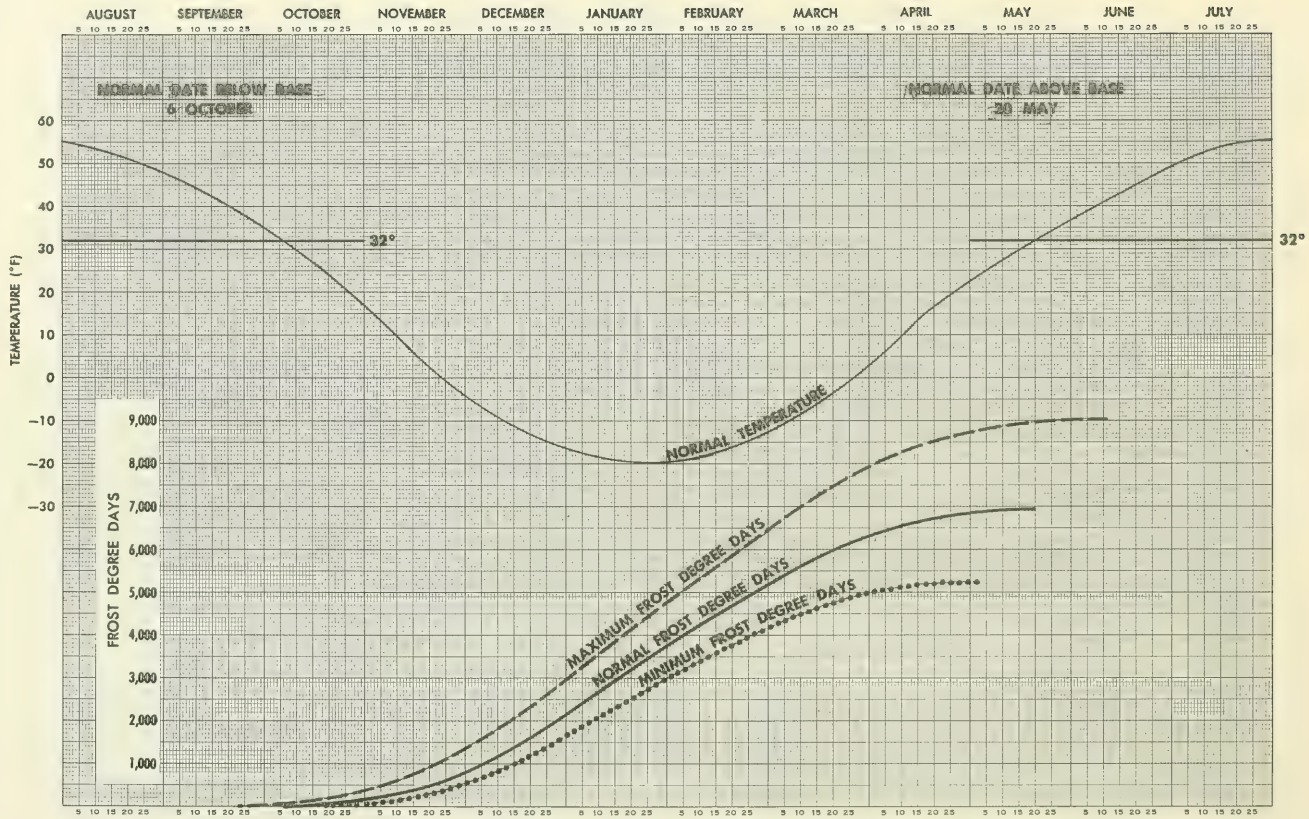

FIGURE 57A CHURCHILL (61 YEARS RECORD)

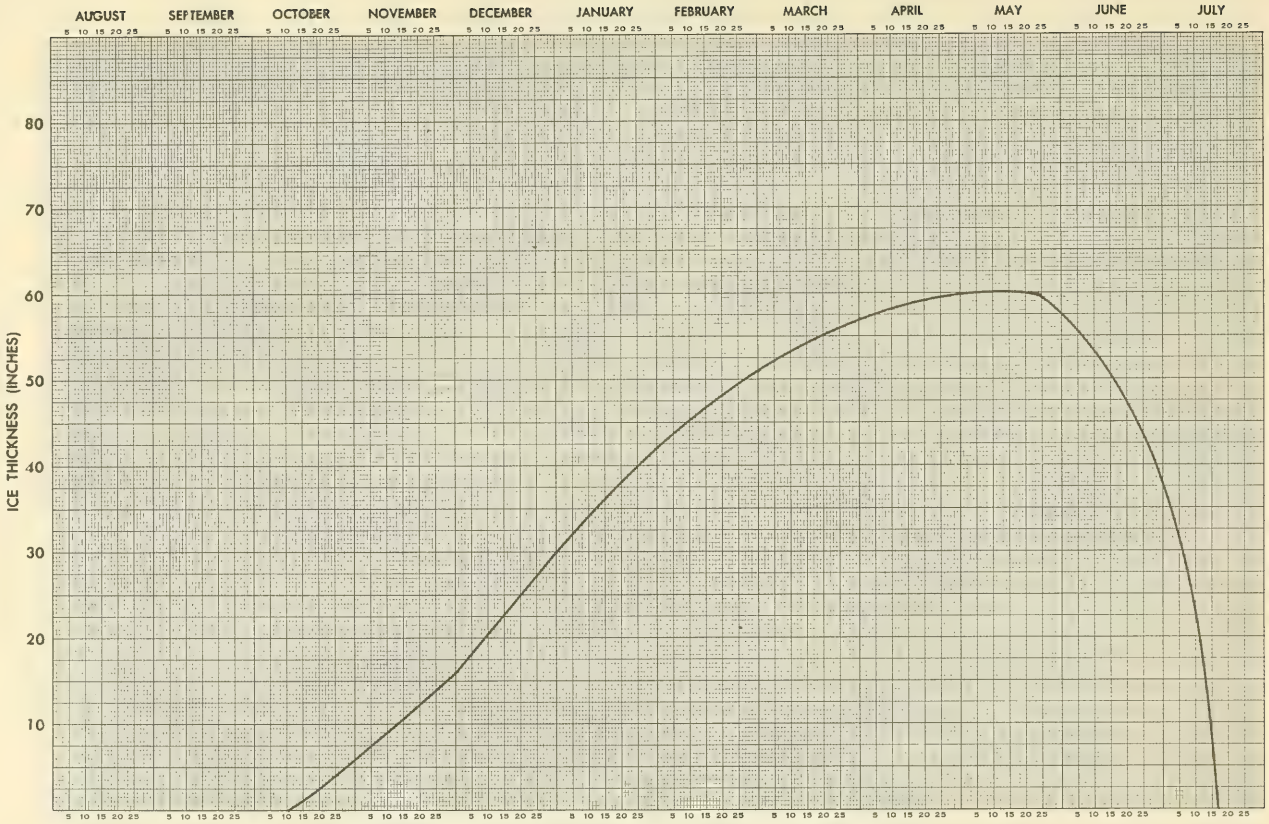

FIGURE 57B CHURCHILL THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

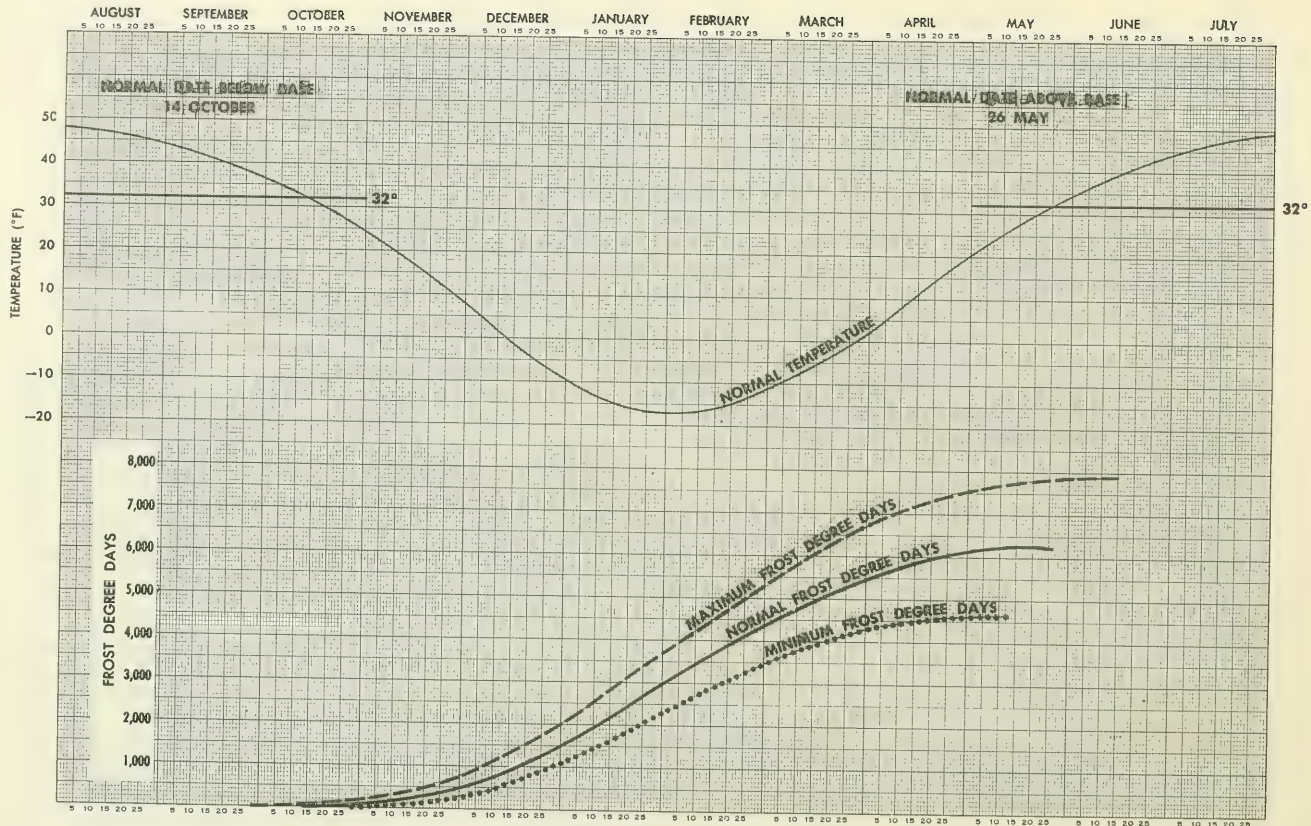

FIGURE 58A PORT HARRISON (26 YEARS RECORD)

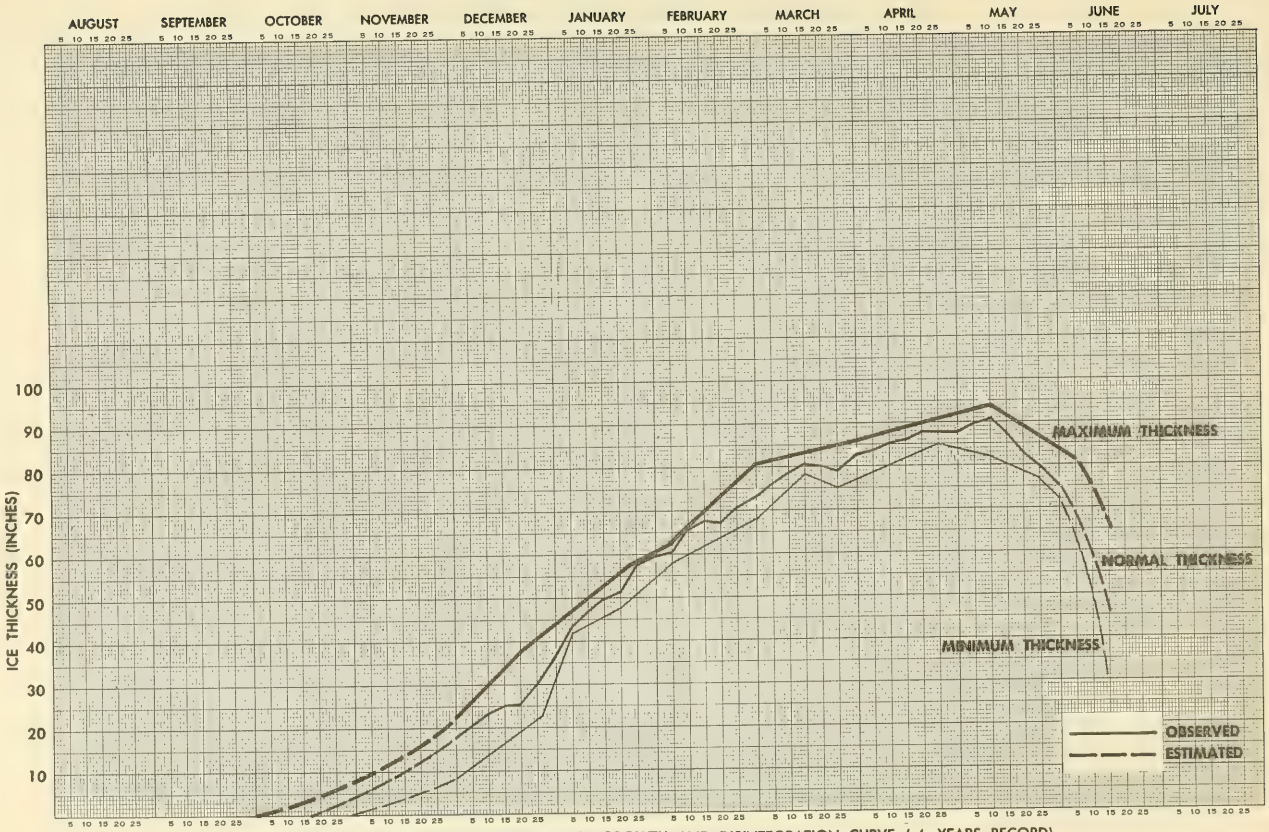

FIGURE 58B PORT HARRISON EMPIRICAL ICE GROWTH AND DISINTEGRATION CURVE (4 YEARS RECORD)

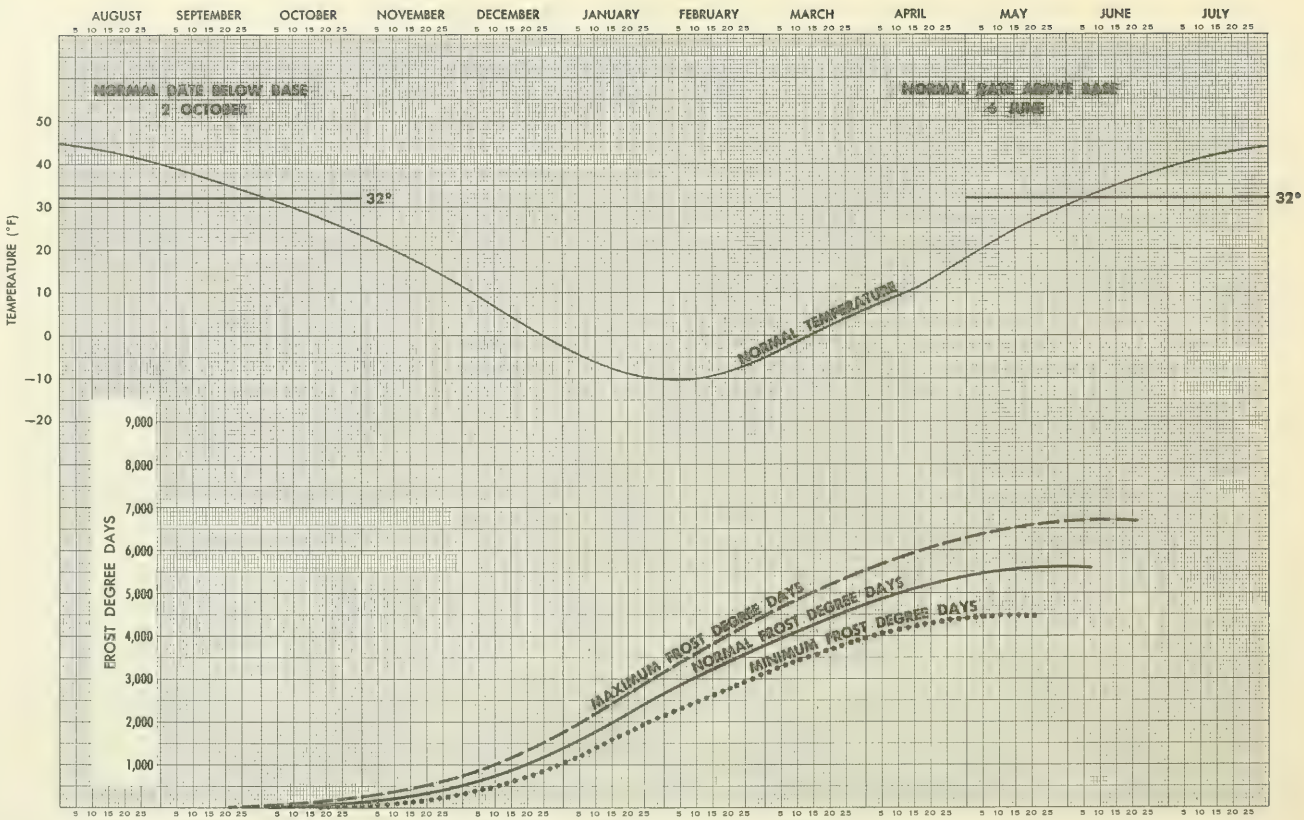

FIGURE 59A CAPE HOPES ADVANCE (12 YEARS RECORD)

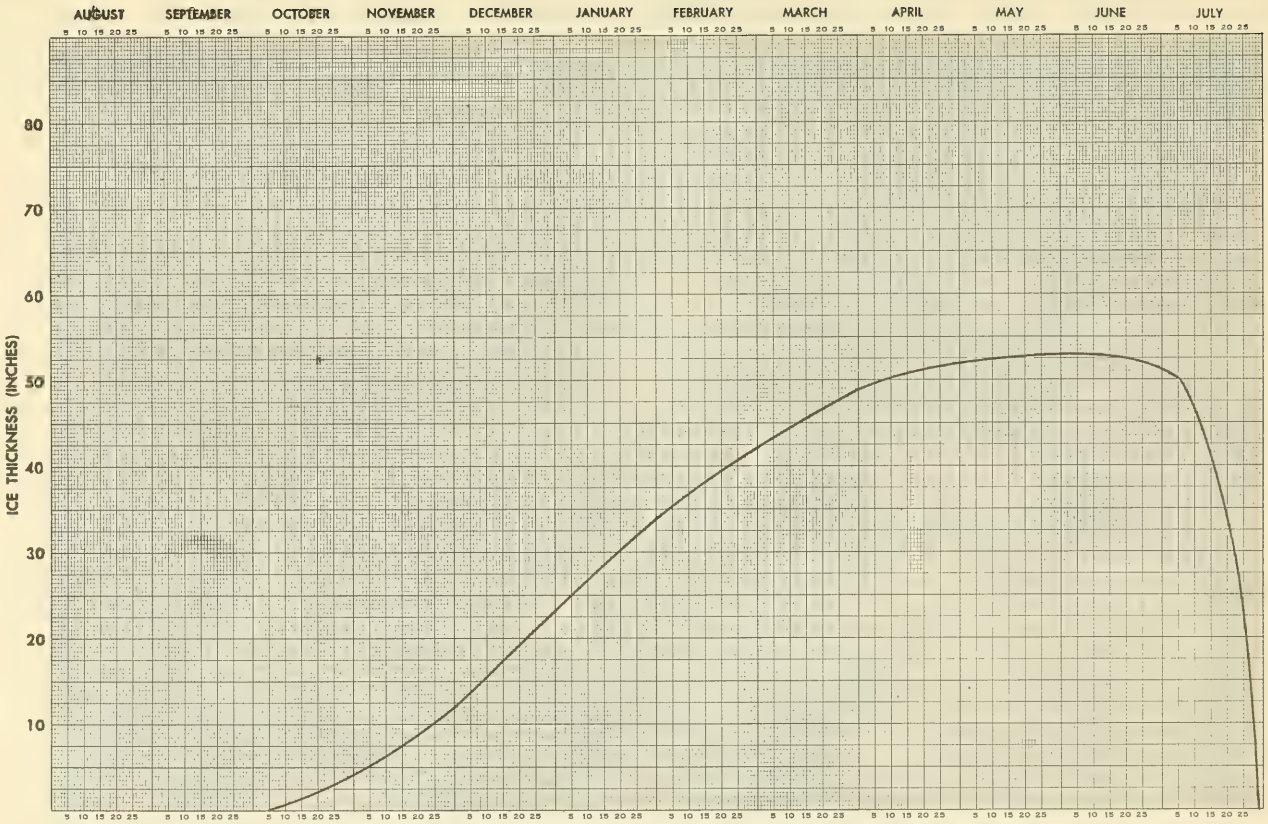

FIGURE 59B CAPE HOPES ADVANCE THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

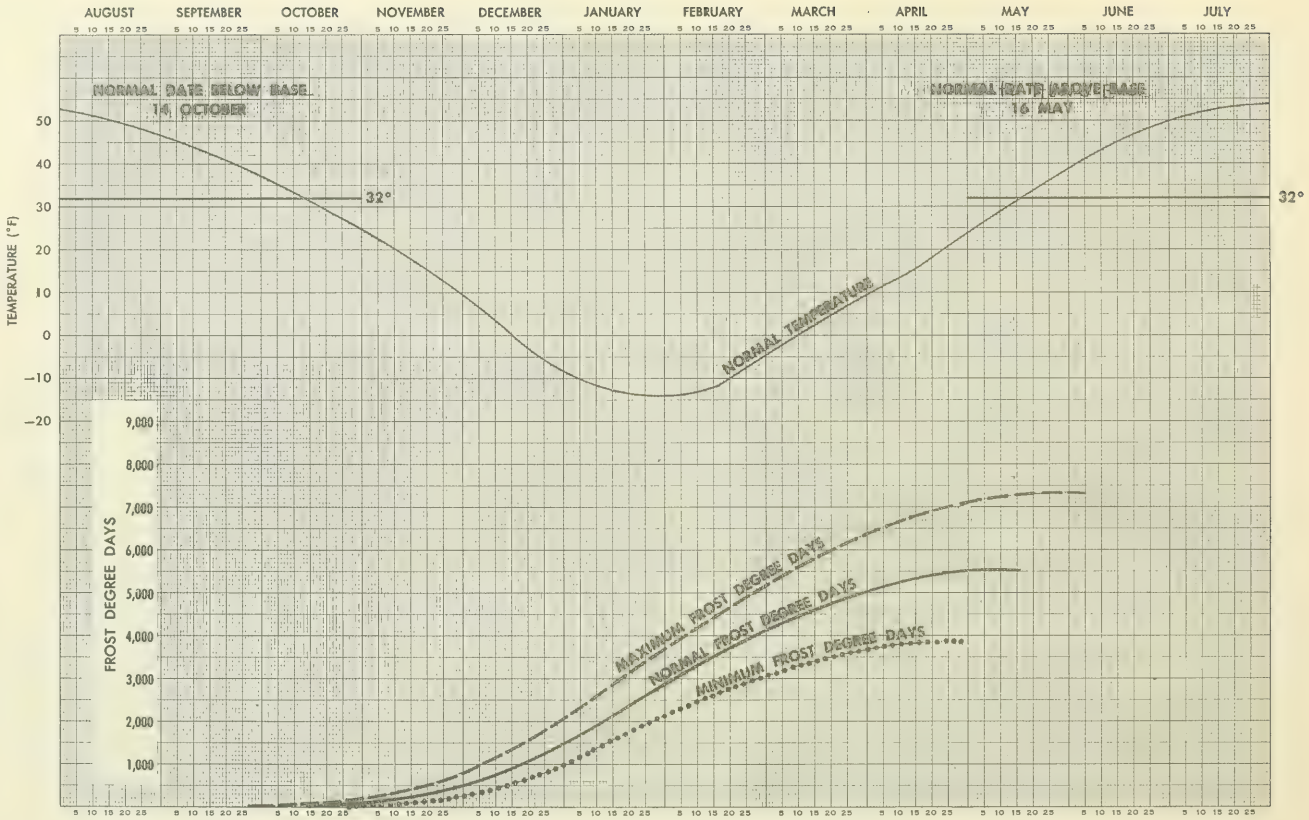

FIGURE 60A FORT CHIMO (10 YEARS RECORD)

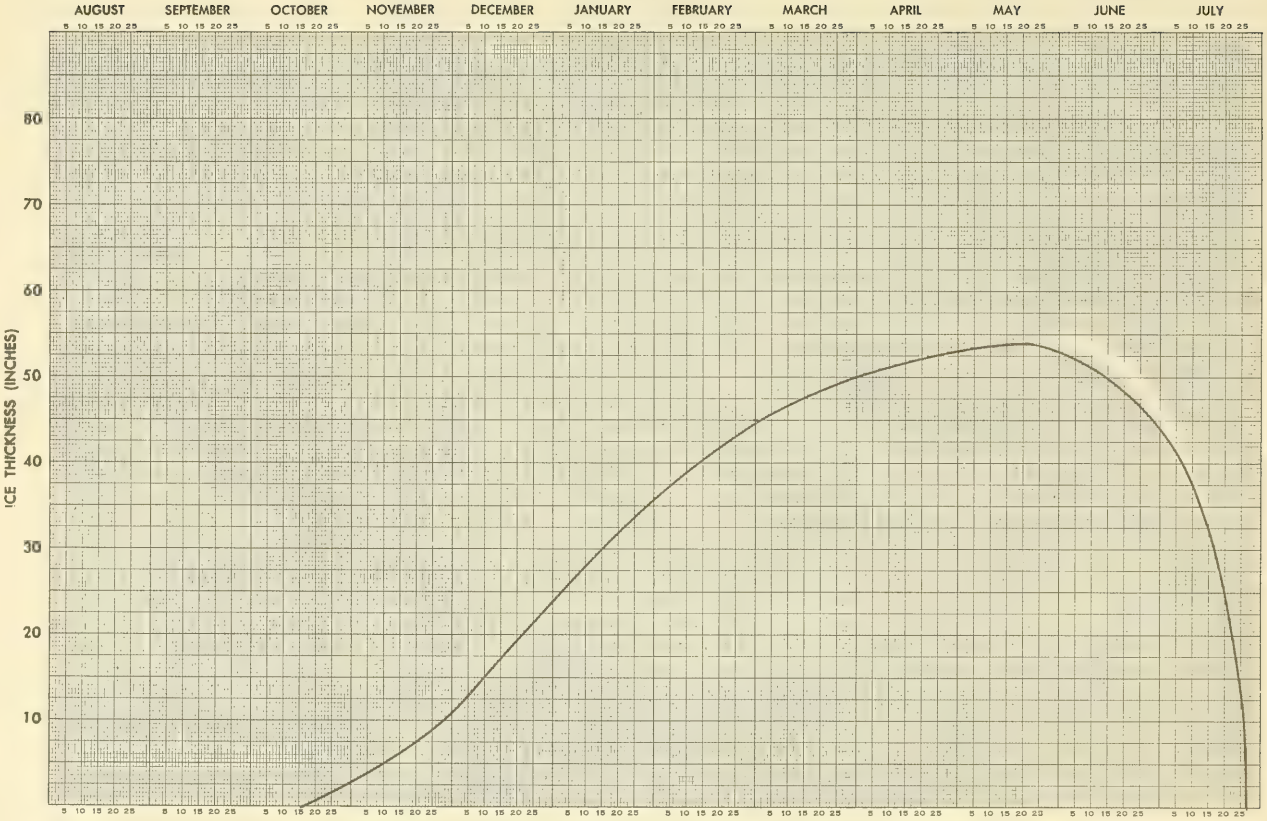

FIGURE 608 FORT CHIMO THEORETICAL ICE GROWTH AND DISINTEGRATION CURVE

UNCLASSIFIED

Security Classification

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13. ABSTRACT

Frost degree day data and sea ice information for selected stations throughout the Arctic are described. Related frost degree day and ice growth curves are graphically illustrated. Harbor breakup and freezeup dates are furnished for selected stations. (U)

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14. KEY WORDS		LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
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FREEZING	TRANSITION TEMPERATURE						
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HARBORS	WATER						
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FROST DEGREE DAY, RELATED ICE THICKNESS CURVES, AND HARBOR FREEZEUP AND BREAKUP DATES FOR SELECTED ARCTIC STATIONS, by Franklin E. Knickern and Gabriel J. Potocsky, July 1965. 123 p., including 118 figures and 2 tables. (TR-60)

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This report presents a compilation of available frost degree day data and sea ice information for selected Arctic stations. Related frost degree day and ice growth curves are depicted in graphic form. Harbor freezeup and breakup dates which include earliest, latest, and average dates of freezeup or breakup are given for selected stations.

1. Breakup Dates
2. Freezeup Dates
3. Sea Ice Growth
4. Frost Degree Day Relationship to Sea Ice Conditions

i. title: Frost Degree Day, Related Ice Thickness Curves, and Harbor Freezeup and Breakup Dates for Selected Arctic Stations

ii. authors: Franklin E. Knickern and Gabriel J. Potocsky

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